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The Elements of Vision: The Micro-Cosmology of Galenic Visual Theory According to Ḥunayn Ibn Isḥāq

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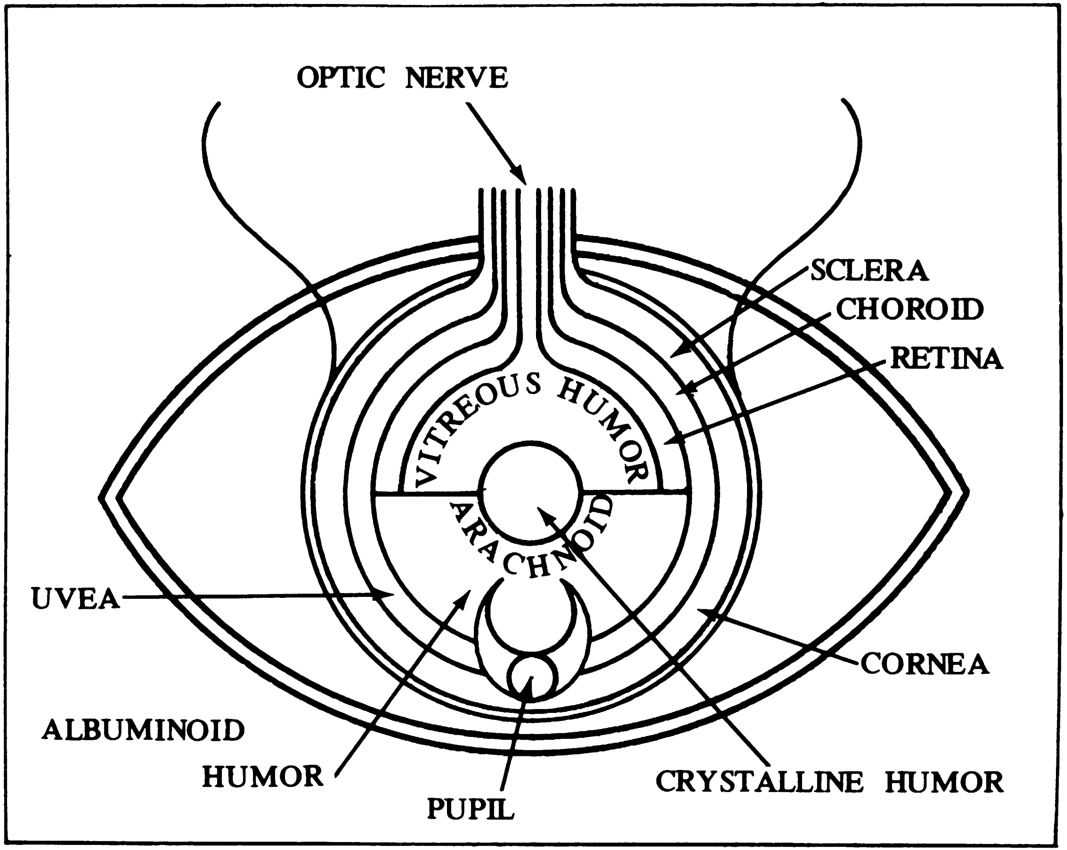

FIG. 1. Anatomy of the eye according to diagrams in the manuscripts of Ḥunayn's *Ten Treatises* (Reprinted from *Theories of Vision from Al-Kindī to Kepler*, fig. 5, by David C. Lindberg by permission of The University of Chicago Press.)

I. INTRODUCTION

In the history of medieval visual theories, one can discern three traditions, each of which seems to have a distinctive approach to vision. The mathematical, medical, and physical-philosophical traditions of medieval visual theory provide important insights and arguments in response to very specific questions defined by the respective interests of these traditions.[1] Each of these traditions also appears to have a larger framework of assumptions, within which it conceives, states, and solves its specific questions concerning vision.[2] Within the medical tradition the theory of Ḥunayn ibn Isḥāq[3] (A.D. 808–873) seems to have been the most important in the medieval Islamic world, and his theory involves a comprehensive set of assumptions which are only partially explicit in his *Ten Treatises on the Eye*. These assumptions are cosmological in nature, and they direct the thinking applied to specific questions at every stage of the theory's development.[4]

Ḥunayn's theory of vision is, in fact, a theory of the cosmological natures of the pathway from the brain to the perceived object. His theory is not a mechanical theory—there are no mechanisms involved—nor is it a causal theory in the usual modern sense of that word. More specifically, the theory is not even a functional theory, insofar as "function" denotes activity and efficient causality. We may, however, consider it a functional theory in a teleological sense, using final causality. Rather than *acting* in a modern physiological sense, the parts of the eye simply *are* beings with natures. Every nature has its end, or goal, built into it and thereby permits, or enables, certain results to occur. The results, in turn, are predetermined in general, but not always specifically, by Nature. (Specific variation or prevention of natural results occurs because of hindrances, such as disease or injury.) Ḥunayn's doctrine of natures, derived from cosmological principles and applied to the microcosm of the eye and vision, is in no way original with him. It is Galenic in character and, like much of Galen's thinking, even pre-Galenic in origin, but Ḥunayn appears to derive the principles of his micro-cosmology of vision directly from Galen's writings. The essential doctrines in this cosmology appear to be four:

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[1] David C. Lindberg, *Theories of Vision from al-Kindi to Kepler* (Chicago: Univ. Chicago Press, 1976), presents the first thorough history of his subject. The three traditions, which he nicely identifies and uses to organize much of his material, appear at pp. x, 1, and then throughout the volume.

[2] While I make no pretense here to identify or even to hint at the larger frameworks for the mathematical and natural philosophical traditions, I would contend that they exist and that, like the medical tradition discussed below, these larger frameworks exert real control on the elaboration of the specifics of the individual theories.

[3] Edited and translated by Max Meyerhof in *The Book of the Ten Treatises on the Eye Ascribed to Ḥunain ibn Is-ḥâq (A.D. 809–877).* Cairo: Government Press, 1928). For permission to quote extensively from this work I thank the General Organization for Government Printing Offices, Embaba, Cairo. For a useful introduction to Ḥunayn, see the article by Georges C. Anawati and Albert Z. Iskandar, "Ḥunayn ibn Isḥāq al-Ibādī, *Dictionary of Scientific Biography*, ed. C. C. Gillispie et al. (New York: Scribners, 1978), Supplement 1: 230-249.

[4] Both David Lindberg and Emilie Savage-Smith offered very useful criticisms of this paper, enabling me to eliminate many errors and overstatements. I also thank an anonymous reader for very thoughtful suggestions. None of these generous commentators should be associated with errors or inadequacies of this paper, for which I remain solely responsible. I am indebted to the College of Physicians of Philadelphia for reproduction in section I of this study of my general description of Galenic medical cosmology, printed in *Transactions and Studies*, ser. 5, vol. 2 (1980): 276–277; I adapt and expand upon various points made in the rest of the same article (pp. 276–283).

(1) Structural order—the arrangement of the parts of the eye reflect a cosmic harmony; that is, each part is a connection between two other parts whose natures are sufficiently dissimilar to require an intermediary, and the order of contiguous parts establishes relationships allowing every part to fulfill its natural purpose.

(2) Medical teleology—every part, by its nature, has purposes, sometimes more protective, sometimes more effective; the reason for existence of each part is determined primarily by the ultimate purpose, vision, and secondarily by the more immediate natures which dictate how the ultimate purpose will best be served.

(3) The four elements—each element is related to one of the senses (the fifth sense based on a combination of two elements), and the capabilities of each sense are outlined in terms of the relevant element(s).

(4) The four qualities—subordinate to the doctrine of the four elements, this doctrine appears in Ḥunayn's work primarily as a doctrine of the qualities of the purest form of elemental fire, light, whose essential characteristic is luminosity. Other qualities than those of light apply to other parts of the eye as well as to other senses. It should be added here that Galen and Ḥunayn also deal in a much greater spectrum of qualities than the basic four (hot [derivatively, luminous], cold, wet, dry), and these additional qualities come from actual observations via dissection. However, these additional qualities will still be found to fit within and to support the ordered structure of parts, which Ḥunayn sets forth so carefully.

While all the above doctrines are essential to Ḥunayn's theory, a retrospective view will show that the doctrine of the elements seems to provide the direction for the development of Ḥunayn's discussion. The other doctrines support and extend the correspondences based on the doctrine of the four elements. The "elements" of Ḥunayn's theory of vision, then, show us a miniature (a micro-analysis) of principles ordering the cosmos. This microcosmology, as the reader will learn, is not simply a rhetorical framework for independent, "scientific" teachings but is the framework which gives meaning to the scientific teachings of Ḥunayn on vision. To divorce the so-called "physiology" of vision (specific problem-solutions) from the cosmology can lead one to find teachings which are not there and to miss teachings which are there.

II. THE FIRST TRACT: THE NATURE AND STRUCTURE OF THE EYE

Of Ḥunayn's *Ten Treatises on the Eye*,[5] tracts 1–3 are the basis for any discussion of vision. The first tract deals with the nature and structure of the eye.[6] The organization of this first treatise in the book embodies a total conception of the working of the eye,[7] beginning with a statement of the hierarchy of the parts of the eye. The hierarchy is determined by the special function of the eye, sight, which is present in only one of its parts. All other parts exist only "to serve that part which performs the function."[8] Like the structure of the eye itself, Ḥunayn's presentation focuses first upon the lens, in which vision occurs, then upon those parts which support and complete its connection posteriorly to the brain, and next upon the parts which support and complete its communication anteriorly with the external air and the visible world. The order and rhythm of Ḥunayn's presentation here are perhaps as impressive as the detailed contents.[9]

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[5] Above, n. 4. I use only this work of Ḥunayn, as it is the basis for all that is said in the much briefer, summarizing *Book of Questions on the Eye*; see the ed. and transl. of Paul Sbath and Max Meyerhof, *Le livre des questions sur l'oeil de Ḥonaïn ibn Isḥāq* (Cairo: Institut Français d'Archéologie Orientale, 1938).

[6] Ḥunayn, pp. 3–14. Here and subsequently I refer to Meyerhof's edition and translation of Ḥunayn's *Ten Treatises* simply as "Ḥunayn" with page numbers.

[7] Meyerhof's subtitle to his edition and translation is "The earliest existing Systematic Text-book of Ophthalmology." While Ḥunayn follows Galen rather extensively (primarily Galen's *De usu partium*, bk. 10, and also, when dealing with the visual pneuma, Galen's *De placitis Hippocratis et Platonis*, bk. 7), Ḥunayn's treatment is more systematic than Galen's. Galen tends to deal with each point in detail and then make a general statement whereby the integration of that point into a larger picture is *more or less* explained. This state of affairs seems explainable partly by Galen's orientation of his works, for example a work concerned primarily with the "usefulness" of the parts of the body, including the eye; we are also well-advised by Owsei Temkin, "On Galen's Pneumatology," *Gesnerus*, 8 (1951): 180–189, that *systematic* Galenism is post-Galenic. This systematizing may be due in part to the closer association of philosophy and medicine, esp. from ca. 600 on, as noted by Leendert G. Westerink, "Philosophy and Medicine in Late Antiquity," *Janus*, 51 (1964): 169–177, esp. 175, where Westerink comments that this state of affairs was subsequently common to both Byzantine and Oriental science.

[8] Ḥunayn, p. 3.

[9] Lindberg, *Theories*, p. 33, says, "The popularity of the Galenic theory [of vision] is explained not simply by the fact that it had been taught by the 'Prince of Physicians' and therefore found a natural audience among medical people, but also by the fact that it included anatomical and physiological detail not present in any other ancient theory of vision. If one's purpose was to treat diseases of the eye, what mattered was not so much the geometrical features of the perception of space as the anatomical features of the eye." So far, so good, but it seems appropriate to observe further that the subsequent history of Galen's theory of vision drew much strength from the more systematic presentation given by Ḥunayn. Later writers who attacked Galen most stridently drew upon his philosophical weaknesses *and* the looseness of his medical explanations to support their attacks. Both al-Rāzī (d. 925), who does not take

Ḥunayn concisely describes the lens as "white, transparent, luminous, and round." (The roundness, as he soon explains, is not perfect sphericity.) These characteristics determine its nature and indicate its purpose. The whiteness, transparency, and luminosity of the lens "receive the changing of colours rapidly, since a white, transparent, luminous thing is quick to receive colours, for instance transparent glass and similar substances."[10] As Ḥunayn points out later[11] the effecting of each of the five senses depends upon a part which is like the objects of its sensation. The qualities of the lens are those which match the materials it works with in vision—purity of color (white), pure fire or light (luminous), and the clarity of pure air (transparent). With such extremes, rather than mixtures, of purity the reception of color will be the quickest possible. With regard to the shape of the lens Ḥunayn records two purposes: first, ". . . roundness serves [to prevent] it from being easily exposed to lesions, since any shape except the round one is very liable to receive injuries on account of its edges;" second "Its flattened form enables it to receive impressions of more perceptible objects than would be the case if it were perfectly round; for a flattened body meets more of the objects which are in its path than does a perfectly spherical body."[12] With these two qualities Ḥunayn nicely exemplifies the Galenic penchant for maximizing the wisdom of Nature. More to the point, we see here the tendency to describe anatomy in teleological terms, complementing the description of physiological function. The shape of the lens both protects and effects. Longevity (durability, permanence) and function are inseparably bound up in this shape. By combining the two so closely Ḥunayn recalls the obvious—that the design of the eye is the design of provident Nature.

Ḥunayn makes extensive use of Galen's *De usu partium*, bk. 10, for ocular anatomy, but Galen's two statements of purpose for the shape of the lens are different; Ḥunayn appears to have contrived a revision of Galen's understanding. Speaking of the flattened "sphere" of the lens, the earlier writer gave as its purposes (1) the security of attachment to the iris, since a perfect sphere would form a less firm bond at its largest periphery, (2)

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an Aristotelian line, and al-Fārābī (d. 950), who does take an Aristotelian philosophical approach, raise "doubts" concerning Galen as a systematic writer. Averroes' (d. 1198) *al-Kulliyyāt* (*Colliget*), bk. 2, consistently favors Aristotle over Galen in matters of logic and method of explanation. On these general criticisms of Galen see J. Christoph Bürgel, "Averroes 'contra Galenum'," *Nachrichten der Akademie der Wissenschaften in Göttingen*, Philologisch-historische Klasse (1967), no. 9: pp. 265-340, esp. 276-290. A good example of a later critic of Galen is Maimonides (d. 1204) whose twenty-fifth medical aphorism is entitled "The Holy War for Independent Scientific Investigation Against Galen"; see *The Medical Aphorisms of Moses Maimonides*, vol. 2, transl. Fred Rosner and Suessman Muntner (New York: Yeshiva U. P., 1971), pp. 171-222. Maimonides records "doubts" concerning Galen's theory of vision on systematic grounds (pp. 177-178) as well as unacceptable statements elsewhere in Galen's medical writing on logical and methodological grounds (e.g. pp. 182-183, 206). Surely the systematic quality of Ḥunayn's presentation of Galenic visual theory is important in explaining the influence of Galen *by way of* Ḥunayn.

[10] Ḥunayn, p. 3.

[11] Ibid., pp. 37-38.

[12] Ibid., pp. 3-4.

the increase in amount of surface area exposed to lines from object to lens when the lens retains the same maximum diameter and is somewhat flattened.[13] Ḥunayn offers a generally Galenic account of the lens's shape, giving both protective and effective characteristics, but it is certainly not Galen's account. In detail Ḥunayn's picture is the opposite of Galen's. Where Galen conceives of the greater security of a flattened sphere, Ḥunayn speaks of the maximum benefit of full roundness. Again, Galen uses diagrams to show that flattening will increase the proportion of effective surface of the lens. He appears to be thinking as much about the economical character of Nature as about the effectiveness of the lens and to be arguing that Nature would not ignore the otherwise unused sections of the lens's surface, so that a partially flattened sphere is not only more effective but also is less wasteful. This second purpose, (the effective), says Galen, is the more important of the two (effective, protective). Ḥunayn, however, avoids making one characteristic distinctly subordinate to the other. His statements support a thoroughly complementary and interdependent, though not necessarily equivalent, system of attributes. Ḥunayn's second purpose stresses the visual field rather than the effective proportion of the surface of the lens as does Galen. Because Ḥunayn neither presents nor refers to a diagram, we can only surmise what he imagines. Most likely he means that rays which pass just beyond the periphery of a perfect solid sphere will be intersected by the same body when flattened, since the major axis of the flattened sphere (retaining the same surface area) will be greater than the diameter of the perfect sphere. Rather than a misunderstanding of Galen,[14] this would seem to represent a modification of Galen, for his argument on the matter, while correct, is purely internal in its emphasis upon the efficiency of the functioning lens, while Ḥunayn stresses the amount perceived of the outside world.

The contrasts between Galen's and Ḥunayn's treatments relate to their larger differences in orientation. Galen emphasizes efficiency of the lens as such; Ḥunayn stresses effectiveness in surveying the outside world. Galen shows that with a given diameter the flattened sphere has more receptive surface than does a perfect sphere of the same diameter; Ḥunayn says that with a given sphere, flattening produces a larger maximum diameter and so receives more from the outside world. Galen's argument is based on geometrical analysis; Ḥunayn's argument involves a simple increase in diameter of reception to achieve an increase in field of vision. Where Galen shows teleology by analysis, Ḥunayn shows teleology by construction.

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[13] These two purposes appear respectively at X, 6 and X, 15 of Galen, *On the Usefulness of the Parts of the Body*, transl. Margaret T. May (Ithaca, N.Y.: Cornell U. P., 1968), 2: 479, 502-503. Note that Galen has separated his protective and effective descriptions here; characteristically Ḥunayn brings his own together for greater systematic value.

[14] Lindberg, *Theories*, p. 229, n. 8, observes, "Hunain here distorts and confuses Galen's correct claim . . . ," and refers to the passages from Galen and Ḥunayn here under discussion. Lindberg is correct, if we assume that Ḥunayn is attempting to use Galen unchanged. I have assumed otherwise.

To conclude his discussion of the shape of the lens Ḥunayn claims two proofs for the presence of the visual function in the lens. Each proof is based on the structure of the eye, first appealing to its hierarchy in a combination of final and formal causality, then appealing to sequence and combining efficient and material causality. He says succinctly:

> If we mentioned . . . that its [the lens'] place is in the centre of the eye, then this is a proof that all that surrounds it in the eye was created for it, either to protect it from injury or to be useful to it. Therefore those parts surround it from all sides, whilst it is in the middle itself. And further proof that the vision is in this humour, and not in any other part of the eye, lies in the circumstance that the vision ceases when cataract intervenes between it [the lens] and the perceptible object,[15] and that the vision returns when the cataract is removed from it by couching [operation].[16]

Renewed emphasis on the centrality of the lens,[17] which is not to be found in Galen,[18] confronts us in Ḥunayn's organization of material as well as in his explicit statements. After the two proofs based on centrality, he passes directly to a listing of the humors and tunics anterior and posterior to the lens. The list is ordered from the center out, in each direction. Next follows a beautifully symmetrical diagram of the ordering of the parts of the eye,[19] with the lens quite central. (The earliest diagrams, however, date only from the late twelfth century.) Finally, to introduce the latter part of tract 1, Ḥunayn says,

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[15] Here Ḥunayn repeats Galen's view of cataract in *Usefulness*, x, 1 (transl. May, pp. 463-464). Ḥunayn's understanding of cataract as well as his treatment for it are found in his fifth tract, p. 50, in his sixth tract, pp. 68-69, and near the end of his ninth tract, pp. 122-123.

[16] Ḥunayn, p. 4.

[17] While the comparison does not allow me to push conclusions, I find it neatly coincidental that even surviving manuscript diagrams point up the systematic as well as detailed differences between Galen and Ḥunayn. In the oldest extant Greek manuscript, also claimed to be the best by its editor, Vat. Urbin. gr. 69, f. 118 (10-11 cent.), there appears a very unsymmetrical schema of the eye and its parts. In the oldest illustrated manuscript of Ḥunayn's *Ten Treatises* (Cairo, MS. ṭibb Taimūr 100: Meyerhof's MS. C), dated A.D. 1196, the schema of the eye's anatomy is thoroughly symmetrical; anatomical diagrams appear at pp. 314, 318, 319, 342, 343 in this manuscript. A photograph of the Greek Galen schema appears in M.T. May's transl. of Galen, *Usefulness*, vol. 2, frontispiece. A photograph of the Arabic Ḥunayn schema appears in Ḥunayn, opposite p. 74 (Arabic text), fig. 1; found also in Stephen L. Polyak, *The Vertebrate Visual System* (Chicago, 1957), p. 16, fig. 2; see my figs. 2-3. I am indebted to the Egyptian National Library (Dar al-Kūtūb) for reproduction of the two MS. illustrations in my figs. 2-3. For further MS. information see Fuat Sezgin, *Geschichte des arabischen Schrifttums* (Leiden: Brill, 1970), III, 251-252. Sezgin's first and fourth MSS. listed are the two used by Meyerhof. Sezgin's second MS. (Foto, Cairo, ṭibb 1350) is a photocopy of Cairo ṭibb Taimūr 100 (Sezgin's first MS.!). Sezgin's third MS. was in the possession of one Zābītā as of 1938; the description in Paul Sbath, *Al-Fihris, Catalogue des manuscrits arabes* (Cairo: Al-Chark, 1938), I, 42, gives only the title and no further information; its present location seems to be unknown. The upshot of this manuscript information is that no further MSS. than those used by Meyerhof are presently locatable. For all information on the MSS. listed in Sezgin I am indebted to Emilie Savage-Smith (Von Grunebaum Center, UCLA).

[18] Galen, *Usefulness*, X, 4, transl. May, p. 475, speaks of the cornea as if it were quite close to the lens, suggesting that the lens is much closer to the front of the eye and not in its center. Galen nowhere commits himself to a geometrically central position for the lens. However, the distance between lens and cornea is also considered to be rather large by Galen in speaking of the couching operation for cataract (*Usefulness*, X, 4, transl. May, 478). That Ḥunayn does not interpret this ambiguity to mean that Galen really considered the lens geometrically central can be inferred from Ḥunayn's translation of Galen's *De usu partium*, wherein Ḥunayn carefully follows Galen and does not say the lens is central. This last information I owe to Emilie Savage-Smith, who has used the Escorial Arabic MS. 850 and the Paris BN MS. arabe 2853 of Ḥunayn's translation.

> I now begin the explanation of the utility of all the humours and tunics which we have described including their origin, their nature, their end and their situation. I have already explained to you that the ice-like humour [the lens] is in the centre of the eye and that there are behind it one humour and three tunics and in front of it one humour and three tunics.[20]

The utility of each part is shown by its relationship to the lens. This relationship emerges in an account of the place of origin, qualitative nature, purpose, and location of each. The lens remains the focus.

In discussing the utility of the humors and tunics, Ḥunayn chooses to present those behind the lens first. The choice is not arbitrary, for it leads to an initial consideration of those parts which connect the lens to the brain and make the lens, as it were, the foremost and sensate part of the nerve from the brain. Ḥunayn does not state the case this baldly, nor does Galen, his primary source. However, Galen generally treats the nerve of each sense as the sensitive part, and while he notes the differences in this regard between vision and the other senses, he clearly holds in mind the general model for all the senses and modifies it only slightly for vision. In his work *De usu partium* the retina is described as an extension of the brain to the eye and not to be called a separate tunic.[21] The retina meets the lens and forms a circle on contact with it. The lens, while a separate part, is the completion of the unit extending from the brain.[22] Ḥunayn, similarly, describes the unit extending from brain to lens. However, he organizes his information more effectively.

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[19] Concerning the illustrations, see also below, n. 50. Beyond the manuscript illustrations themselves, there are some variations in detail among the modern copies of Ḥunayn's schema for ocular anatomy. Meyerhof, for example, apparently carried away by the notion of symmetry, made the retina extend beyond the aranea and lens to the pupil! The errors in Meyerhof's drawing (Ḥunayn, p. 5) as well as in Polyak's labels to his own drawing (wrongly delimiting the uvea, *Vertebrate Visual System*, p. 17) are noted and corrected by Lindberg, *Theories*, p. 35, fig. 5; p. 229, n. 14. Meyerhof notes that "the Greek and Arabic anatomy" understood uvea and iris interchangeably to refer to the ciliary body; see Ḥunayn, pp. 8, n. 1; 9, n. 3. That Ḥunayn made no distinction is clear from his consistent use of the term *'inabiyya* (e.g. Arabic text pp. 8, 79, 81, 100, 101, 122) for both *uvea* and *iris*. May, in her transl. of *Usefulness* (p. 468, n. 10) observes that Galen's *iris* is not the same as the modern meaning but that the term was used in the modern sense before Galen. The significance of the *iris* (uvea), a section through the ciliary region, for Galen is that it defines the place where all the tunics come together; Ḥunayn gives this point less prominence.

[20] Ḥunayn, p. 6.

[21] *Usefulness*, X, 1-2, transl. May, p. 465.

[22] Ibid., pp. 467-468 (bk. X, 2); p. 686 (XVI, 3); ". . . the soft nerve [the optic nerve] has properly been inserted into the principal instrument of sight itself in the eye . . ." A correlative statement appears in Galen's *De placitis Hippocratis et Platonis*, VII, 5: "after entering the eye, it [the optic nerve] . . . becomes like the brain in all respects" (ed. and trans. Phillip De Lacy, Corpus Medicorum Graecorum, V 4, 1, 2, Berlin, Akademie Verlag, 1980, p. 456, lines 23-25).

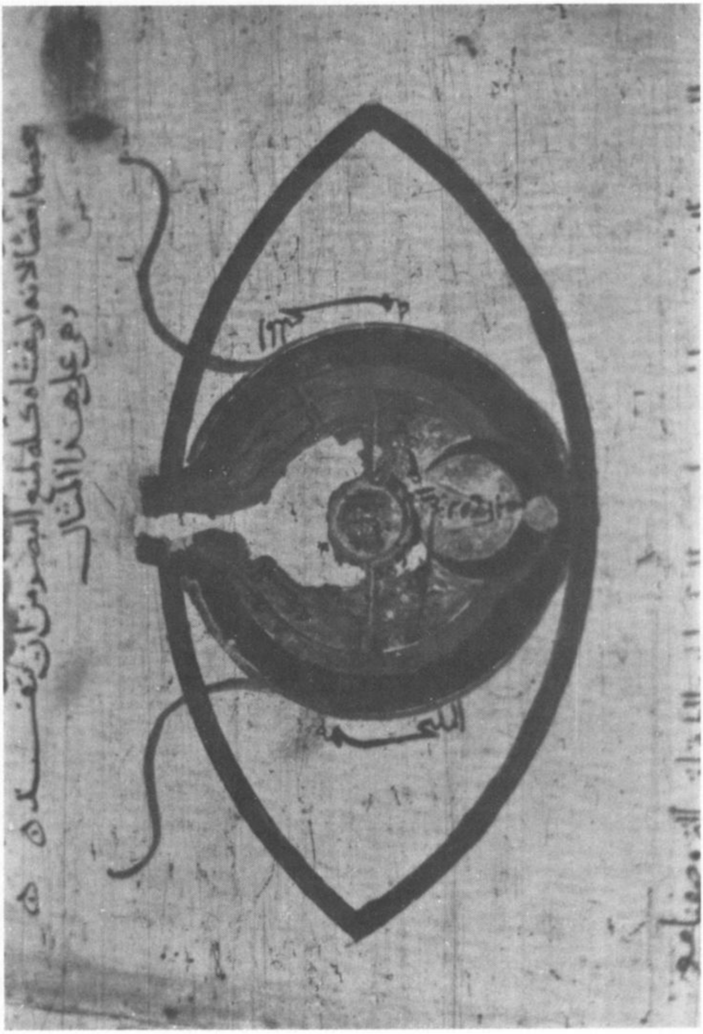

FIG. 2. Ṭibb Taimūr ms. 100, p. 314 (see nn. 17, 19, 50).

A highly suggestive passage opens the discussion of the parts behind the lens.

> We say: every one of the members of the human body requires nourishment, and this without doubt because there is a continual loss of its substance going on through dissolution by reason of the influence of the natural warmth from within and the warmth of the air from without. For this reason it requires a substance to replace that which has been dissolved. But nothing can replace the dissolved substance except that which resembles it, *i.e.* something similar in nature to the member in question. The nutrition is effected in this wise, *viz.* that the member receives an addition of substance resembling its own nature. This accretion, however, can only resemble the nature of the member if the latter transmutes it according to its own nature. A substance is most quickly transmuted into the thing which resembles its own nature most closely. Since the lens without doubt requires nutriment and since, as we mentioned already, this humour is white, transparent and luminous, it is impossible for it to receive its nutrition direct from the blood. It requires an intermediary between its nature and that of the blood; and such is the glass-like humour [the vitreous], as it is nearer to the white colour and transparency than the blood. Therefore the vitreous is adjacent to the lens without any partition, and it [the lens] is half submerged in it [the vitreous].[23]

Ḥunayn frames his explanation of the vitreous humor within a general doctrine of nutrition, which rests in turn upon a natural-philosophical conception of matter and its interactions. Nutrition, one of the three natural faculties,[24] is essentially a faculty to maintain a state, unlike the other two Galenic faculties of genesis and growth. The faculty acts through attracting and modifying nutritive substance until it is qualitatively similar to the organ to be supported. The similar substance is retained and anything else is expelled.[25] The result is a steady state of the nourished organ, for natural heat is constantly using up (by dissolution) the substance of the organ.[26] The consequences of such attrition when not redressed should be discussed under the heading of diseases. Here we concern ourselves with the means of preserving a balance. Like the Galenic view of coction, Ḥunayn's view requires addition of like to like. Obviously there must occur some process to change unlike to like. But what Ḥunayn says seems strange to the modern scientist insofar as no mechanism of change is forthcoming. The association of like with like is not simply an end product; it is also a goal-oriented *process*—an implicit mechanism operating through final causes rather than through efficient causes. The thought is common in Galen, e.g. the transformation of air to nutriment[27] and the transformation of air to psychic pneuma.[28] As Ḥunayn says, the nature of the transmuting organ identifies the characteristics of the product, assuming the organ operates healthily and "according to its own nature." What he is describing is a passage from difference to identity. The multiplicity of steps provides for gradual change, following the commonplace (Aristotelian, Galenic) that Nature proceeds by small steps ("requires an intermediary") rather than leaps. The conception is persuasive in part because contiguity is brought to bear on continuity. We have the vitreous humor, as Ḥunayn says, "adjacent to the lens without any partition and . . . half-submerged in it." The two are *almost* continuous locally. Likewise the qualities of the vitreous are "nearer to" those of the lens than any other part of the eye. The two are *almost* continuous qualitatively. Finally, the product, or nutriment, itself effects the maintenance of a healthy steady state, because the qualities are identical with the organ nourished.[29] Like begets like; like affects like. The process of nutrition follows a philosophical conception of material action which Ḥunayn uses to account for both the nature and the activity of all the senses and especially vision.[30]

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[23] Ḥunayn, p. 6. Lindberg, *Theories*, pp. 34–35, quotes a bit more than half (the latter half) of this text and calls it "an interesting example of ancient and medieval physiological reasoning." In choosing not to analyze the text Lindberg passes by an essential part of Ḥunayn's understanding of vision.

[24] Ḥunayn, p. 41.

[25] Ibid., on the four faculties of nutrition, viz. attracting, altering, retaining, and expelling.

[26] The importance of heat in both health and disease can be learned by looking at Ḥunayn's fourth tract, where warmth appears as a component (a) of the natural complexion (p. 41) of the body and its parts, (b) of the simple diseases, which are based solely on balances of the four elemental qualities (pp. 42–43), and (c) indirectly and intermittently a factor in the compound diseases (characteristics of the simple diseases appear again sometimes among the compound, pp. 43–45). An extreme example of the effects of excessive heat appears in tract 6, on symptoms of diseases of the eye: "The phantasms originating in the brain are caused by the disease the Greek name of which is *phrenitis*; it is a hot swelling in the brain when a swelling occurs in its anterior part. It is as follows: when the hot dry chyme in the brain is burnt by the heat of fevers, there rises from it a fume like that of oil burnt in the fire. When this fume penetrates to the eye by the arteries leading to it from the brain, it produces in it the various kinds of phantasms." (p. 71).

Having presented a major step in the protection (by way of maintenance) of the lens, our author introduces into the discussion the effective part of vision. This comes easily through an account of the next contiguous posterior part, the retina. This tunic contains veins and arteries for nutrition plus a hollow nerve as passage for the visual pneuma, the active medium for vision in the eye. Ḥunayn simply notes these two aspects of the retina and then remarks, "Here it is necessary to stop the explanation and take up the discussion from the beginning."[31] The "beginning" is the brain, which is "the source of all sensation and all motion and . . . from it the faculty of sensation and the faculty of motion proceed through the nerves into all the sensory and motor organs."[32] Rather than discuss each posterior tunic separately, he treats them together as distinct layers of the nerve from the brain to the lens. In this way, the notion of ultimate unity and purpose of the parts is preserved and even emphasized, with the individual purposes of the successive tunics clearly subordinate to the general purpose. Tracing each layer from the brain to the eye we find: (1) outermost, the sclera, a thick and hard membrane, which is suited by its nature to protect the inner parts of the nerve from injury as well as to help fix the eye in place; (2) medially, the chorioid, thin and soft, filled with veins and arteries, suitable for nourishing the structure within it; (3) innermost, the optic nerve proper, or retina, filled with arteries and veins for transmitting nutriment to the vitreous and thereby to the lens. This three-fold structure encloses and exists for the optic canal with visual pneuma communicating between brain and lens. Ḥunayn describes it as follows:

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[27] *Usefulness*, VII, 8, transl. May, p. 346: "For it is reasonable that the outer air does not become the nutriment of the pneuma in the animal's body suddenly and all at once; rather it is acquired gradually, just as the food is too, and over a period of time *acquires the quality proper* (my emphasis) to the innate pneuma, the principal instrument of this alteration being the flesh of the lung. . . ."

[28] Ibid., p. 347: "The outer air drawn in by the rough arteries receives its first elaboration in the flesh of the lungs, its second thereafter in the heart and arteries . . . , and a final one in the ventricles of the encephalon, where its transformation into psychic pneuma is complete." As Ḥunayn echoes in his own treatment of this theme, the production of pneuma is not simply a quantitative attenuation of matter, but rather a refining and subtilizing qualitatively of a substance, achieved by an organ through final, not efficient, causality; Ḥunayn, p. 18. See also Galen, *De placitis*, VII, 3, De Lacy p. 446, ll. 3–10: "If nature, needing to fashion semen and milk with precision, even though they are far inferior in power to psychic pneuma, nevertheless contrived for them a lengthy stay in the organs of coction . . . , it is reasonable that also when making psychic from vital pneuma in the brain it constructed close to the brain a complex labyrinth, so to speak, the retiform web."

[29] Thus Ḥunayn, in tract 4, p. 40, speaks of "the preservation of health in healthy bodies by the application of homogeneous things . . . if the natural thing is known, that which is homogeneous to it is known, and this being known, its contrary is also known, and if homogeneous things be applied and contrary things avoided, then health is preserved."

[30] Ḥunayn, tract 2, p. 16; tract 3, pp. 28, 33, 35–39.

> . . . there is no hollow nerve in the body except this [the optic nerve]. The reason is that the eye needs the psychic[33] pneuma in order to effect the vision by means of it . . .[34] through its nerve [the retina supplies] the sense of feeling and the luminous pneuma, which effects the vision, to the lens.[35]

The singularity of the sense of sight is marked by its anatomy as much as by the characteristics of its perception. While the "faculties" of all motion and all sensations pass via nerves from brain to organs, only in the sense nerve for sight is there passage of visual pneuma, or spirit, itself. At present we learn the anatomical fact. The full physiological and philosophical significance appears in the subsequent treatises of Ḥunayn's *Ten Treatises*, but initially we record the fact that a substance with identifiable quality (luminous) is peculiar to vision among the senses.

The remainder of tract 1 parallels in form of presentation the earlier part. The humor and three tunics anterior to the lens are presented—in order, with their qualities and corresponding purposes.[36] Continued emphasis is given to the hierarchy in the structure of the eye by means of the order of presentation in Ḥunayn's text. Outermost is the conjunctiva, next the cornea, third the uvea. Each of these tunics corresponds to one of the posterior tunics and derives from a layer passing from the brain to the eye.[37] The conjunctiva is modestly effective, primarily protective.[38] The properties of the cornea ("thin, white, solid and hard") make obvious its purposes: to protect the lens from injury (solidity, hardness) and "to allow the passage of light through it and not to hinder it [in any way]" (thinness, whiteness).[39] The innermost tunic, the uvea, has three purposes:

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[31] Ḥunayn, p. 7.

[32] Ibid.

[33] I modify Meyerhof's translation, "animal," at this point, preferring "psychic" instead. The Arabic term is *nafsānī*, literally "spiritual" or "psychic," (Arabic text, p. 77, line 7) and is used consistently by Ḥunayn in this treatise for what we call psychic pneuma (as indicated by Meyerhof on p. 18). For "vital" pneuma Ḥunayn uses the word *hayawānī*, which actually means "animal." Galen's usages are obviously intended, and Ḥunayn, like Galen, speaks only of vital and psychic ("animal") pneumata; there is nothing about a third "natural" pneuma. See generally Owsei Temkin, "On Galen's Pneumatology," *Gesnerus*, 8 (1951): 180–189. Meyerhof translates *rūḥ* as "spirit," and I have modified the translation throughout, for *rūḥ* is Ḥunayn's translation for *pneuma*.

[34] Ḥunayn, p. 7.

[35] Ibid., p. 8.

> (i) to nourish the cornea, and this because the cornea cannot contain veins and arteries sufficient for its alimentation on account of its thinness, hardness and solidity, (ii) to separate the lens from the cornea in order to prevent the former from being injured by the latter, (iii) to concentrate the light by its colour. . . . In its colour is black mingled with sky-colour to concentrate the light by which the vision is effected, so that it may not be dissipated by the external light. In its centre is a hole to permit the passage out into the air of the light to meet the perceived.[40]

The uvea protects both lens and cornea, giving nutrition to the latter as well. With the effective purpose of the uvea the reader encounters an adumbration of the fuller description, to be found later, of the primary agent of vision, the visual pneuma. Here Ḥunayn calls it "light," to indicate its similarity in character to "external light." He says that the quality of the uvea, its color (nothing said about shape!), concentrates the visual pneuma, giving it strength to lessen the likelihood of dissipation by light from the outside world.[41] Only after this concentration does the pneuma pass "into the air" through the hole, or pupil, in the uvea. This leads Ḥunayn immediately to identify the albuminoid (aquaeous) humor, the anterior humor corresponding to the vitreous, behind the lens:

> In the hollow of the uvea is the albuminoid humour and there passes [through it] a luminous pneuma. The general purpose of both is to separate the lens from the cornea, lest the latter should hurt it. And the albuminoid humour has the special function of moistening and nourishing the lens, so that it shall not be dried up by the air, and of moistening the uvea, so that it shall not be dried up and hardened and thus damage the lens when it comes in contact with it. The luminous pneuma effects the vision when it unites with the external light.[42]

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[36] Ibid., pp. 8–12. I omit reference to the closing section (pp. 13–14) on the muscles of the eye and the lid, which Ḥunayn covers for medical completeness, pointing out their function "to move it [the eye] in the directions in which it looks" (p. 13).

[37] Ibid., pp. 4–5, 8–9, located in somewhat obscure phrasing in the latter place.

[38] See Ḥunayn, pp. 5, 9, 11, 12 on the location of the conjunctiva; p. 13 on its effective use (to unite the eye to the bone); pp. 9, 13 on its protective use (to cover the inner layers).

[39] Ibid., p. 9.

[40] Ibid., pp. 9–10.

[41] Thus Galen says, ". . . the essence of this visual faculty is of the nature of light. . . . it is destroyed when it is dispersed by abrupt association with a brighter, stronger light . . . "; *Usefulness*, X, 3, trans. May, p. 472.

[42] Ḥunayn, p. 10.

The albuminoid humor is highly protective by moistening the parts it touches. Like the vitreous, the albuminoid too nourishes the lens. The effective purposes of this anterior humor are rather passive, as it simply keeps in place the contingent parts and provides a good medium for the visual pneuma to pass from lens to cornea, the boundary with the outside world.[43] While this section of the text puts us on the border of a discussion of the visual act itself, Ḥunayn stops short in accord with his intention of discussing only anatomy in tract 1. As an essential part of anatomy we have seen a listing of purposes, both protective and effective, of the tunics and humors of the eye. These purposes are fit neatly into the hierarchical structure of the eye.

To close the first tract Ḥunayn reveals that some dissent may exist over the number of tunics. Interestingly he opens the account with an ambiguous treatment of the aranea, or arachnoid membrane, actually a hypothetical tunic.

> Between the lens and the albuminoid humour there extends over half the lens a very thin husk, resembling the peel of an onion or a cobweb, to protect it [the lens] from the uvea and from injuries from without.[44] Therefore some people asserted that the tunics of the eye were seven in number, others that there were six of them, others five, four or three, and some even that there were only two. The difference between them is one in term only and not in meaning. Those who say that the tunics of the eye are seven in number count the retina, the choroid, the sclerotic, the membrane covering the external half of the lens, the uvea, the cornea and the conjunctiva. . . . Those who assert that there are only six tunics of the eye do so because they say that they see no reason why they should call the retina a tunic, since according to them, the use of [a tunic] is to protect [the parts] over which it is spread, whilst it is not the function of the retina to protect.[45] Those who speak of five also see no reason to call the membrane which covers half the lens a tunic, but say that it is [only] a part of it. Those who say that there are four. . . . The tunics are [disposed] in the manner shown by the diagram.[46] This is what we wished to make clear concerning the tunics of the eye, in order that nobody should think that there was a difference [of opinion] between the Ancients on the subject of the tunics and humours of the eye.[47]

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[43] Similarly Galen, *Usefulness*, X, 4, transl. May, p. 475: "Only at this perforation is there no intermediate tunic between the hornlike tunic and the crystalline humor, and only here the association and mingling of the inner and outer light occurs as if through very thin, clear horn."

[44] Meyerhof here points out that this hypothetical tunic is actually the anterior capsule of the lens; Ḥunayn, p. 10, n. 3.

[45] Meyerhof here adds the word "anything" as object of the verb "to protect" (Ḥunayn, p. 11, line 16). The addition creates a specificity which is misleading and false.

[46] At this place in the translation (p. 12) Meyerhof inserts a diagram of the eye's structure, essentially the same as appears earlier (p. 5) and with the same error in extending the retina beyond the lens. See above, n. 19. A photograph of the original illustration to the text appears in Ḥunayn, opp. p. 80 (Arabic text), fig. 2. Both MS. illustrations contain a label for the arachnoid (*'ankabūtiyya*), which is my concern here. It is as Lindberg, *Theories*, p. 35, fig. 5 (my fig. 3), places it.

[47] Ibid., pp. 10–12.

Ḥunayn closes the discussion with a caveat that no argument exists on his part with the ancients, and he implies that arguments by others with the ancients display ignorance of the meaning of the sources. Even more to the point for an understanding of Ḥunayn is a review of his treatment of the arachnoid, for he initiates the supposed controversy with that item. Does he consider it a proper tunic? Apparently not. Nowhere in the discussion does he refer to it as something *he* would call a tunic. He first calls it "a very thin husk" and later simply a "membrane." In his earlier, complete list of tunics and humors[48] there is no mention of the arachnoid. In explaining why different writers have mentioned different sets of tunics he notes that those favoring seven give the arachnoid; those favoring six will omit the retina (*not* the arachnoid!), since it does not function "to protect." Yet Ḥunayn clearly lists the retina as a tunic and maintains a broader sense of the protective function of a tunic, including the protective meaning of nutrition, which maintains a state of health in the eye. It is those who favor five tunics who exclude the arachnoid as "a part of" the lens. But Ḥunayn favors six tunics as he emphasizes more than once in tract 1. While offering a Galenic conception of the eye Ḥunayn surreptitiously departs in this matter of detail from Galen's anatomy.[49] The reason for the departure has been apparent. Ḥunayn's continuing concern in presenting an anatomy of the eye has been a concern for order. The symmetry of the single humor and three tunics in front of the lens with the single humor and three tunics behind is important enough to Ḥunayn that he decides against the arachnoid as a separate tunic.[50] The value of such symmetry in creating an image of integrated structure seems uppermost in his thinking.

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[48] Ḥunayn, p. 4.

[49] Galen explicitly mentions the arachnoid as a tunic in *Usefulness*, X, 6, transl. May, pp. 478–479. He gives the matter extended discussion in *On Anatomical Procedures*, trans. W. L. H. Duckworth, M. C. Lyons, B. Towers (Cambridge: Cambridge U. P., 1962), pp. 40–43, not only listing the arachnoid as a tunic but telling why it is properly called a tunic. Ḥunayn obviously chooses not to follow Galen in this rationale. Note that Ḥunayn revised and corrected both the Syriac and the Arabic translations of this treatise using three Greek MSS. (ibid. p. 13).

[50] Nowhere else in *Ten Treatises* does Ḥunayn mention the arachnoid membrane. Its inclusion in *both* diagrams in the late 12th-century manuscript raises suspicion, since one of these diagrams illustrates a text where the arachnoid is not to be found. It seems more likely that the diagrams are to be suspected than the text, for the diagrams appear only in the latter of the two manuscripts used. The arachnoid seems to be mentioned in neither manuscript at the point where Ḥunayn gives his initial list, symmetrically arranged, of two humors and six tunics in addition to the lens. See Meyerhof's discussion of the manuscripts in Ḥunayn, pp. xlvii–xlix; also in Meyerhof and Carl Prüfer, "Die Augenanatomie des Ḥunain b. Isḥāq," *Archiv für Geschichte der Medizin*, 4 (1910–1911): 165–166.

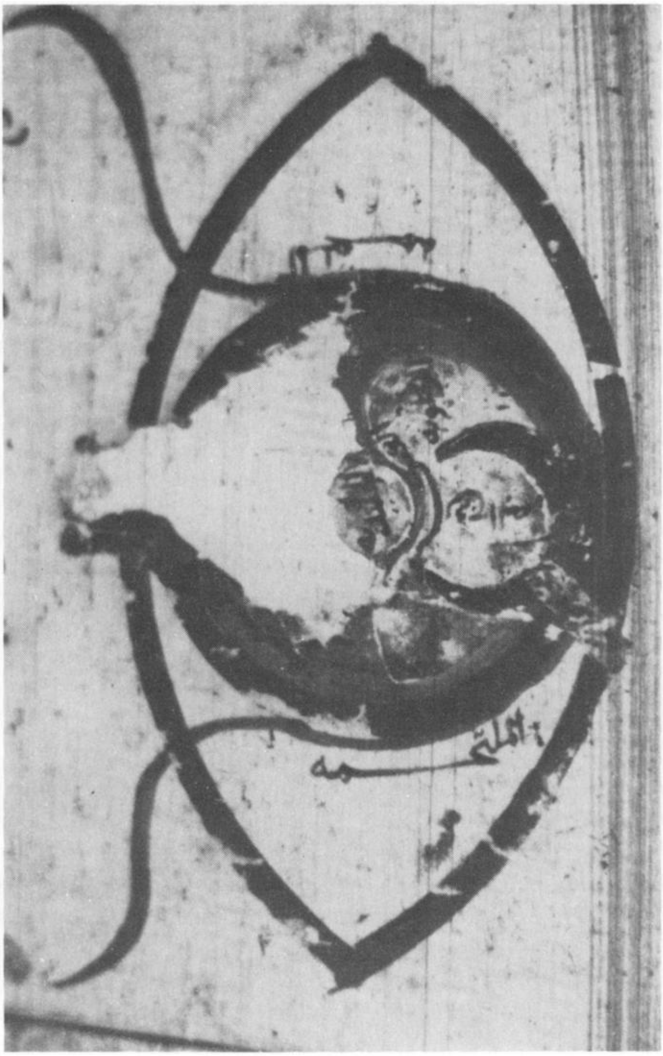

FIG. 3. Ṭibb Taimūr ms. 100, p. 342 (see nn. 17, 19, 50).

III. THE SECOND TRACT: THE NATURE AND USES OF THE BRAIN

Just as the first tract was organized around a unified sense of structure of the eye, the second presents the nature and uses of the brain as part of a larger picture—the senses in general. The highly ordered structure of the eye in tract 1 is given fuller meaning by the natural harmony of the senses as introduced in tract 2. The reader gains awareness of an ordered microcosm within which the sense of sight is to be understood. While much briefer than its predecessor,[51] tract 2 provides both a framework for the former and a preparation for the tract to follow, "on the subject of vision." In scholastic fashion Ḥunayn engages his subject gradually, beginning with a basic set of qualities and functions.

> Now one learns the nature of a thing either by its definition or by the distinctive properties which are peculiar to it. Therefore it is important for us to know what the condition of the brain is, and what are the conditions peculiar to it. We say: Every organ is distinguished by two peculiarities and defined by two definitions, one concerning its element, *i.e.* its nature, the other its kind, *i.e.* its function and use. And so the brain is likewise distinguished by two peculiarities, that is to say defined by two definitions. The first, as we have already mentioned, resulting from its nature, is as follows: the brain is a cold organ, the coldest and most humid of all the organs of the body. The other definition resulting from its function and its indispensable character is as follows: the brain is the source of perception, of voluntary movement and of the will. These two definitions are peculiar to the brain and to no other organ.[52]

While Ḥunayn's definitions set the brain apart, they do not isolate it but rather demand a continual return to its connections with other parts, including not only those with which it is functionally related but also those with which it interrelates elementally, by means of its nature. This concern appears quickly, for as soon as he descends through the various functions and functionaries of the brain (movement and perception, muscles and nerves, spinal and cranial, hard and soft nerves), the focus is on the soft nerves, which effect perception. The nature, or element, of each sense engages us first.

> There are five senses and the most delicate of them is vision. The object of its perception is fire and what is of the nature of fire, *viz.* colour. There are three kinds of fire: flame, red heat and light. The proof of the fact that light is fire is that when

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[51] Ḥunayn, pp. 15–19; about half the length of the text of tract 1.

[52] Ibid., p. 15.

it is concentrated in a glass or in a transparent or shining body, it causes burning.

Next to vision the most delicate sense is that of hearing; its object is the air and what occurs in it, *viz.* sound, since sound is only a blow in the air or beaten air. After hearing comes the sense of smell; its object is vapour, and vapour is something between earth and air,[53] and is not far behind the air in subtlety.[54] After the sense of smell follows that of taste; its object is water and what it absorbs [into itself]; for flavour is only possible when the water dissolves something solid and creates warmth in it. . . . The coarsest of the senses is that of touch; its object is the earth and its forms or qualities, *viz.* hardness, softness, warmth, cold, humidity and dryness and what arises from these. All the nerves possess the sense of touch, or . . . feeling.[55]

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[53] Ḥunayn's text here places vapor between earth (*arḍ*) and water (*mā*). If we were to follow strictly the "Galenist" tradition, using such examples as Nemesius of Emesa (late fourth c.), *De natura hominis*, 6, 11 (ed. Matthaeus, in Migne, Patrologia graeca, vol. 40, coll. 636, 657), we would emend the text here to read "air" and "water," for that is the most commonly mentioned pair of elements used to account for vapor. The origin of the notion that vapor is between air and water is to be found in Plato's *Timaeus* 66 D-E, where Plato considers the sense of smell to be of "half-formed" nature on stereometric grounds; see also John I. Beare, *Greek Theories of Elementary Cognition* (Oxford: Clarendon Press, 1906), pp. 141–144. Ḥunayn himself reflects this tradition of vapor-as-air-and-water later in *Ten Treatises*; see below at nn. 164, 168. In this latter place Ḥunayn seems clearly to be using Galen's *De placitis*, VII, 5-6, as a source, and there Galen places vapor between air and water; see ed. De Lacy p. 462, 13–24. However, in three other works, each of which was translated by Ḥunayn, Galen has different statements about the elemental composition of vapor. In *De usu partium*, VIII, 6, ed. Georg Helmreich (Leipzig: Teubner, 1907), vol. 1, pp. 469–470, Galen gives no explicit makeup but only a relative "fineness" of vapor with regard to air and of air with regard to light. In his detailed monograph on the sense of smell, Galen has vapor composed of air, water, and fire; see *De instrumento odoratus*, II, 10–12, ed. Jutta Kollesch (Berlin: Akademie Verlag, 1964), pp. 38–40. In his *Compendium Timaei Platonis*, 15, Galen places vapor between earth and air; see *Galeni Compendium Timaei Platonis*, edd. Paul Kraus and Richard Walzer (London: Warburg Institute, 1951), p. 20. In order to make sense of these variations, the editors of both the *Compendium* and the *De instrumento odoratus* have suggested that the manuscripts are in error and that vapor should be placed explicitly between air and water. However, in a closer study of Galen's writings on the sense of smell, "Galen on the Elements of Olfactory Sensation," *Rheinisches Museum für Philologie* (forthcoming), I have argued that the varying texts should be preserved as they are, for Galen's discussions and his sources strongly support such a conclusion. As a result, in dealing with Ḥunayn's *Ten Treatises* I assume that Ḥunayn uses Galen's *Compendium Timaei* here for the elements (air and earth) associated with vapor, since he uses Galen's *De usu partium* almost continuously to this point, and that work does not list the elements for vapor. Because of the mention of earth in both places (*Compendium* and the present location in *Ten Treatises*), Ḥunayn seems to have turned initially to the *Compendium* to define vapor. Galen's *Compendium* is known today only in Arabic. It was translated from Greek to Syriac by Ḥunayn and then from Syriac to Arabic by ʿĪsa ibn Yaḥya; see Ḥunayn, *Über die syrischen und arabischen Galen-Übersetzungen*, ed. Gotthelf Bergsträsser (Leipzig: Brockhaus, 1925), p. 41, no. 124. Ḥunayn presumably recognizes Galen's divergence in the *Compendium* from the position taken in *De placitis*, where vapor is a mixture of air and water. In fact, Ḥunayn seems to incorporate the divergence in his *Ten Treatises*, using the air-and-earth definition first (changed apparently by a copyist's error to water-and-earth, which makes *no* sense) and the air-and-water definition later at a point in *Ten Treatises* where he is continually making use of Galen's *De placitis*. Beyond the question of elemental composition of vapor, we must consider another issue here. While Galen combines elements and/or qualities without positing a distinctive nature for vapor, Ḥunayn seems to desire a less ambiguous statement about the nature of vapor. Nemesius of Emesa (see ref. at beginning of this note), more systematic in temper than Galen, refers to vapor and odors as a distinct genus, of a nature intermediate between air and water; Nemesius's hypothesis of a distinct nature for the fifth sense (smell) is much more definite than any statement by Galen. Ḥunayn, like Nemesius, has a distinct nature in mind.

The roots of this doctrine are in Empedocles[56] and Plato,[57] passed through the mediation of both Posidonius[58] and Galen.[59] The early emphasis (Empedocles and Plato) was already on the central idea of homogeneous entities interacting. Plato spoke of a "pure" fire which does not burn but gives only light.[60] Galen's notion reflects this by speaking not of fire but of "brightness" as the medium of vision and having the quality of the aether.[61] Ḥunayn's understanding of the tradition is without notable innovation. He simply makes more explicit the understanding of Plato and Galen by listing three kinds of fire. The fire associated with vision does not, at least in its normal form, heat or burn. Light appears to be the most attenuated sort of fire, since concentration of the rays is required to produce significant heat or fire.

Entering into a brief exposition of the natures of the five senses, Ḥunayn uncovers for us a theory of sensation which he will use more extensively in the third tract.[62] The theory has both a principle of order and a principle of correspondence in its outline form. The ordering of the five senses accords with the relative "delicacy," or "subtlety," of each sense. The order produced is: vision, hearing, smell, taste, touch. While it is obvious that this order derives from the stated objects of the senses, the four elements plus an intermediate, the reader must be careful not to associate these objects directly with the Aristotelian quality of relative weight. In Plato and Galen the discrimination is based on a quantitative distinction of size, but only in separating the senses of hearing and smell.[63] The association of quantitative difference with sense difference is systematically

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[54] Here I substitute "subtlety" for Meyerhof's "rarity," which seems to have a more mechanical character than the Arabic text intends (*laṭāf*, see p. 84, l. 18 Arabic).

[55] Ḥunayn, p. 16.

[56] George M. Stratton, *Theophrastus and the Greek Physiological Psychology before Aristotle* (New York: Macmillan, 1917), pp. 71, 73; also Willem van Hoorn, *As Images Unwind* (Amsterdam: U. P. of Amsterdam, 1972), pp. 43-48; see Beare, *Greek Theories*, pp. 14-23, 204-205.

[57] *Timaeus* 45B-D, 67C-68B.

[58] Georg Pfligersdorffer, *Studien zu Poseidonios*, Sitzungsberichte der österreichische Akademie der Wissenschaften, Philosophisch-historische Klasse, 232 (1959): Bd. 5, p. 59.

[59] *Usefulness*, VIII, 6, transl. May, pp. 402-406, where only the senses of sight, hearing, and smell are actually discussed. Galen's detailed account stresses the view that each sense is very specific and requires stimulus of like by like: "It is absolutely necessary for each of the latter [more delicate senses] to be altered if sensation is to occur. They are not, however, all altered by every perceptible thing; rather, the bright, luminous sense instrument is altered by colors, the airlike instrument by sounds, the vaporous instrument by odors, and in a word, like is perceptible by like" (ibid., p. 402). See also *De placitis Hippocratis et Platonis* VII, 5 (above n. 53); *De symptomatum causis*, 6 (ed. Kühn, VII, 122); *De simplicium medicamentorum temperamentis ac facultatibus* I, 37 (ed. Kühn, XI, 445). All of these Galenic sources Ḥunayn says he translated into Syriac and the first (*De usu partium*) into Arabic as well; see Ḥunayn, *Galen-Übersetzungen*, pp. 9-10 (no. 14), 21-22 (nos. 46, 49), 23-24 (no. 53); concerning the successive rescensions of this treatise see Gotthelf Bergstrasser, *Neue Materialen zu Ḥunain ibn Isḥāq's Galenbibliographie* (Leipzig: Deutsche Morgenländische Gesellschaft, 1932), pp. 10-52, esp. pp. 32, 52.

[60] *Timaeus* 45B-C.

[61] *Usefulness*, transl. May, pp. 402, 405.

[62] Ḥunayn, pp. 35-38.

[63] Above n. 53. Plato, *Timaeus* 66 E, says, "All odors are vapor or mist, mist being that which

deemphasized by Ḥunayn, even in dealing with smell. His vocabulary allows on the one hand for a sense of gradient, a relative coarseness or delicacy, but on the other hand not for a type of gradient which has a clearly recognized standard of measurement. That is, weight or even density would allow for quantitative transition from one sense's quality into that of another sense. By insisting on such terms as "subtlety" and "delicacy," Ḥunayn allows a notion of more or less but preserves a conception of qualitative difference. The ordering of the senses is categorical and depends upon an unambiguous distinction of each from the other.

While his principle of order is explicit, his principle of correspondence is here only implied. Briefly, it requires that like be perceived by like, that each sense incorporate the quality which characterizes its objects. The interaction of like with like has already been seen in Ḥunayn's discussion of the nutrition of one tissue by another. This cosmological (microcosmic and macrocosmic) principle will again be used in his account of visual activity, but in the present discussion it is not developed.

Passing from a discussion of nerves to a discussion of the parts of the brain Ḥunayn comes to focus on a substance which is a part of thinking and intrinsic to one of the senses, sight.

> In the brain are four cavities known as the ventricles of the brain, two cavities in the anterior, one in the posterior part and one in the intervening space between the two anterior cavities and the posterior cavity. In these cavities is a psychic pneuma by which those functions are performed which we have mentioned and which cannot be performed without it. The origin of this psychic pneuma is the vital pneuma that arises in the heart. Two arteries ascend from the heart to the brain and when they arrive below the brain, they divide into many branches. Then these branches interlace so as to resemble a net. The psychic pneuma does not cease to circulate in this network until it is rarefied and refined. Then it passes out of the arteries into the two anterior cavities which are in the brain. It [the pneuma] remains there likewise for a time and becomes refined, and nature removes from it all the residue and coarse parts which are intermixed with it into the nostrils and the mouth. Then it passes from the two anterior cavities into the middle cavity and is refined there likewise. Then it passes from the middle to the posterior cavity by way of a canal [existing] between the two cavities. . . . Through the pneuma which is in the posterior cavity movement and the act of recollection are accomplished, through the pneuma which is in the anterior part of the brain observation and imagination, and through the pneuma which is in the middle part of the brain reflection.[64]

Ḥunayn's doctrine of psychic pneuma derives completely from Galen, who explains more fully the process of its formation. The pneuma begins as air and is reformed successively in the lungs, the heart, and the brain. This successive transition is conceived as a gradual process, more harmonious

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is on the way from air to water, vapor what is on the way from water to air; consequently all odors are finer than water, grosser than air. Their nature is plainly seen when a man forcibly inhales the air through something that obstructs the passage of the breath: then no odor filters through with it; nothing comes but the air robbed of all scent." Galen expands on this in *Usefulness*, VIII, 6–7, transl. May, pp. 405–409.

[64] Ḥunayn, pp. 17–18.

and involving no sudden exchange of one substance for its opposite.[65] For Ḥunayn the process of purification continues in the brain so that the psychic pneuma of the posterior ventricle, performing movement and recollection, is still more refined than in either the middle (reflection) or the anterior (observation and imagination) ventricles. However, it is at the anterior cavities, responsible for sensation, that the qualitative refinement producing truly psychic pneuma takes place. These refinements are rather wondrous activities, for they involve elemental transmutations. Ḥunayn starts with the vital pneuma of the heart, which Galen clearly manufactures from air. The gradual character of the transition is again an aspect of final causation as opposed to efficient cause. The transition is basic and therefore requires many steps. As in alchemy, so in humoral medicine and the elemental physiology based on it, multiplication of stages seems to allow remarkable change—a gradual refinement, for example, that has no limits within the realm of nature. As Ḥunayn shows in tract 3, on vision proper, the psychic pneuma, originally inspired air, becomes visual pneuma, which is a kind of fire. Air becomes fire through a multi-stage process, each step very much like the next, explained in terms of the goal toward which the process is directed, not in terms of an efficient causal mechanism. Here a basic cosmic process is exemplified in the production of a substance necessary to explain visual sensation.

His tract on the brain has given Ḥunayn the opportunity to show how the order of nature is reflected in the nature and workings of the senses. Each sense is coordinated with an element. Like the elements, the senses are arranged hierarchically. The psychic pneuma is completed in the brain to enable the functioning of vision, the highest of the senses. And finally, we should notice that the nature of the brain according to Ḥunayn reflects the needs of vision and the other senses. The brain is, he says, cold and humid. Its humidity protects against the destructive aspects of dryness and also supports the working of the soft nerves, which are those of sensation. The coldness of the brain protects against destruction by heat. Ḥunayn even invokes the metaphor of the cool-tempered personality—more than a metaphor in Galenic humoral theory—by remarking,

> . . . if the brain were warm, the thinking faculty would be unstable, since heat is quick to move, whilst cold is quiet and steady. Thought requires stability and solidity; therefore Nature assisted thought by tempering it with cold so that it might be steady. The proof of the above statement lies in the fact that he whose temper of brain is hot has no fixed opinion, is undecided, lacking firmness of resolution and steadfastness.[66]

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[65] Galen, *Usefulness*, VII, 8, transl. May, p. 346: "For it is reasonable that the outer air does not become the nutriment of the pneuma in the animal's body suddenly and all at once; rather, it is acquired gradually, just as the food is too, and over a period of time acquires the quality proper to the innate pneuma, the principal instrument of this being the flesh of the lung. . . ." Further in the same section Galen says, "The outer air drawn in by the rough arteries receives its first elaboration in the flesh of the lungs, its second thereafter in the heart and arteries . . . , and a final one in the ventricles of the encephalon, where its transformation into psychic pneuma is complete." (ibid., p. 347).

[66] Ḥunayn, p. 19.

IV. THE THIRD TRACT: THE WORKING OF THE VISUAL PNEUMA

The content and organization of the third of Ḥunayn's *Ten Treatises* show once more his concern for an order of presentation which reflects the order of Nature. Tract 1 introduces the reader to the structure of the eye in a fashion following that structure and its hierarchy. Tract 2 presents the brain primarily in terms of the senses and the sense nerves, preeminently the sense of vision. At the center of the second treatise the psychic pneuma and its origins appear. This pneuma is the focus of the third tract as well, which discusses (1) the optic nerves, (2) the visual pneuma, and (3) the conditions and enactment of vision. The interrelationship of each of the three treatises remains uppermost in Ḥunayn's work. The first is not simply an anatomy—it omits anatomical material on the optic nerve given in the third tract—but is a framework for what follows. As is the first, so the second treatise (and the third) is purpose-oriented. Each of Ḥunayn's descriptions and arguments is conceived with the ultimate goal, effective vision, in mind. Effective vision in turn can be explained best as a specific result of an ordered, harmonious cosmos—microcosm in terms of macrocosm. Just as the homocentric structure of the outside world mirrors its purpose, so does the similar structure of the inner world. The parallel between outer and inner worlds is shown in detail by application of the standard four-element theory.[67] We have seen the elements used to describe the nature and objects of the senses, and we encounter elemental theory again in the detailed account of vision given in tract 3. Thus Ḥunayn leads the reader from the instrument which channels and projects visual pneuma (tract 1) to the organ which produces it (tract 2) to the actual working of visual pneuma (tract 3).

A. The Optic Nerve

In beginning with the optic nerves[68] Ḥunayn reemphasizes the visual pneuma, for the six peculiar characteristics he gives for the optic nerve all relate to the pneuma, and of the five arguments concerning the junction (chiasma) of the optic nerves, only the two arguments which appeal to the importance of the visual pneuma receive his acceptance as true positions.

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[67] An excellent article on this topic by Rudolf Allers, "Microcosmus: From Axamimandros to Paracelsus," *Traditio*, 2 (1944): 319-407, outlines the basic character of the forms of microcosmology which are behind Ḥunayn's doctrines on the eye and vision: elementaristic microcosmism (pp. 321-322, 344-348) and cosmocentric microcosmism (pp. 322-323, 348-351).

[68] Ḥunayn, pp. 20-27.

The six characteristics[69] are the following. (1) Greater cross-sectional area, appropriate for protecting the internal canal both from within and from without. (2) Hollowness, viz. having a perceptible canal passing from the ventricles of the brain to the retina.[70] (3) Greater softness than other sensory nerves, "to render their sensibility finer,"[71] for the softness as well as the hollowness is conceived to make the visual pneuma flow more effectively—the fineness of one reinforces the fineness of the other. (4) The visual pneuma, a substance, passes in significant quantity from brain to eye, unlike the working of psychic pneuma in other sense nerves, where the effect, or "force," of the pneuma passes along those nerves but not the "substance" of the pneuma.[72] But in the optic nerves the pneuma itself flows all the way, via the nerves, to the uvea. (5) Reaffirming the third characteristic above, he says that the soft interior of the optic nerve retains the nature of the brain so that there is a unique continuity, in the visual nerve, from brain through nerve to eye.[73] (6) Unlike any other sense nerve the optic nerves, which arise separately in the ventricles, join at the chiasma and then separate to connect with the eyes. The nerve originating on the right side of the brain goes to the right eye and similarly with the left nerve. It is this last (sixth) characteristic that provides occasion for five arguments, concerning the purpose of the chiasma.

The reason for conjunction of the optic nerves, a phenomenon peculiar to the nerves of sight, is given in teleological terms. Ḥunayn quickly rejects two arguments based on similarity of the two nerves and on a desirable similarity of conditions for the nerves. A third argument receives longer refutation, pointing out that the conjunction is not needed to protect the nerves. The fourth and fifth arguments, considered together by Galen,[74] deal with the strength and the interrelationship of visual pneuma in the optic nerves. When one eye is unable to see, the pneuma which would normally flow to the blind eye is diverted at the chiasma to the functioning eye. Here we have one of the two essential reasons for the juncture of the optic nerves, and it is shown experimentally by observing the "dimmer and weaker" view of an object close to the eye when a barrier, such as an open hand on the bridge of the nose, prevents both eyes from seeing the object at once. When one eye is closed, the other sees the object much more clearly, for the visual pneuma flows completely to one eye. The increased flow explains the larger size of the pupil, according to Ḥunayn.[75] A greater tension in the pneuma in front of the lens requires a larger opening for exit of the pneuma. Finally, he presents the ultimate reason for the chiasma—to prevent double vision. Galen's account of the chiasma is somewhat simpler and clearer than Ḥunayn's. Galen reports that the axes of the cones of visual rays begin in the brain, and one can imagine straight lines from brain all the way to viewed object. The part played by the chiasma in this is to provide a crossing of the two straight visual lines, since this suffices to guarantee that the lines of vision will be in one plane and thereby avoid double vision (in that plane).[76] As Galen testifies, this plane, the horizontal, is the only plane on which double vision cannot occur.[77] The character of Galen's argument is quasi-mathematical. While Ḥunayn follows the sense of Galen, the description is more elaborate in the later account, and the emphasis is less on the geometrical character of the argument (as in Galen) and more on the anatomical details.[78] Ḥunayn is more intent on constructing for his audience a mental image than on following mathematical argument. His image includes an emphasis on the singularity of the intermediate origin (the chiasma) of the visual rays, so that we find not only an interrelationship of intersecting straight lines but a relationship of equilinear corresponding visual rays. There is no suggestion of an equal time of passage but there is implied a concern for equality of distance traveled and for identical shape of image. These reinforce the purpose of properly superimposed images from the two eyes.

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[69] Ibid., pp. 20-23.

[70] Friedrich Solmsen, "Greek Philosophy and the Discovery of the Nerves," *Museum Helveticum*, 18 (1961): 150-167, 169-197, notes that Herophilus considered the optic nerve hollow and a carrier of pneuma. He especially recommended the optic nerve for study, since the hollow was visible and clearly present (pp. 187-188). See also Galen, *On Anatomical Procedures*, XIV, 2 (trans. Duckworth, Lyons, Towers, pp. 187-188) for discussion of hollow optic nerve and chiasma.

[71] Ḥunayn, pp. 21-22.

[72] Solmsen, "Discovery of the Nerves," 187-188, also notes that Herophilus had already hypothesized the existence of pneuma in the other sense nerves, as recognized by Galen.

[73] Above, n. 22.

[74] As noted by Meyerhof (Ḥunayn, p. 24, n. 1); see Galen, *Usefulness*, X, 13, transl. May, pp. 498-499.

B. THE PNEUMA ITSELF

Having discussed the pathways of the visual pneuma, Ḥunayn turns to the nature and workings of the pneuma itself.[79] In the medical tradition to which he is heir the existence of this visual pneuma remains unquestioned and of great utility. In the empirical tradition it goes back through Erasistratus to Herophilus;[80] it comprises an integral part of Stoic pneumatic ideology;[81] with Galen it provides continuity from mind to sensed object and offers various advantages.[82] Essential to these advantages is its material, substantive reality. As such the visual pneuma allows vision to be treated in para-tactile terms and thereby to be understood similarly to the other senses. A substantive visual pneuma also permits—even encourages—more mechanical explanations of the different stages of the visual process. Finally, the material nature of the pneuma brings it within the well-understood theory of the material elements and allows the rich store of relevant analogical reasoning to be applied. Certainly these advantages are recognized and displayed by Ḥunayn.[83]

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[75] Ḥunayn, p. 25.

[76] *Usefulness*, X, 13, transl. May, pp. 498-499.

[77] Rudolf E. Siegel, "Principles and Contradictions of Galen's Doctrine of Vision," *Sudhoffs Archiv*, 54 (1970): 261-276, esp. 270, points out in detail that Galen's conception of double vision was wrong. Yet Siegel's reasoning and evidence stand even more as explanation for the *strength* of Galen's account in its day. Galen's conception fits well both with evidence and widely accepted beliefs of the time.

[78] Ḥunayn, pp. 25-26.

[79] Ibid., pp. 27-31.

[80] Solmsen, "Discovery of the Nerves," 181, 187-189.

[81] Shmuel Sambursky, *Physics of the Stoics* (New York: Macmillan, 1959), pp. 10, 23, 24, 27-29; David E. Hahm, *The Origins of Stoic Cosmology* (Columbus: Ohio State U. P., 1977), ch. 5 (cosmobiology), esp. pp. 157-168 (Chrysippus' *pneuma*), 169-173 (Stoic *tonos*).

[82] Siegel, "Principles and Contradictions," 273-274.

His discussion of the visual pneuma leaves the reader with a sense of the analogous activity of the nerves in all the senses and even of the similarity between the action of sense nerves and the nerves of voluntary muscles. In this Ḥunayn is thoroughly Galenic and draws not only on Book 7 of *De placitis Hippocratis et Platonis* but also on such works as Galen's *De motu musculorum.* Both voluntary muscles and the senses act in response to the *psyche* and are distinguished from the province of *physis* (nature).[84] For Galen the arteries and veins make a part of the body alive (*physikon*) at the lowest level—vegetative; the nerves add to such a part its relationship to the *psyche* and bring animate activity.[85] The Galenic synthesis of bodily sensation and movement via the pneuma is exactly what Ḥunayn presents in his initial discussion of the visual pneuma proper. The visual pneuma, he recalls,

> . . . is a kind of animal pneuma since it originates in that animal pneuma which enters the two anterior ventricles of the brain, where it is thoroughly matured, subtilised, purified and extracted and arranged, as we mentioned before, according to the nature of the brain. This pneuma is of the sensitive variety, as vision is unique among the senses, the noblest of them and the most superior in quality.

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[83] Interestingly, the outmoded character of the doctrine of visual pneuma had led modern translators to depreciate and avoid its presentation by Ḥunayn. For example, Meyerhof and Prüfer, "Die Augenanatomie," p. 167, carefully abridge Ḥunayn's third treatise, "von denen wir jedoch den zweiten und dritten Teil des dritten Buches fortlassen, welche eine endlose phantastische Erörterung über den Vorgang des Sehens enthält." Again, the same authors, in "Die Lehre vom Sehen bei Ḥunain b. Isḥâq," *Archiv für Geschichte der Medizin,* 6 (1912-1913): 21-33, remark about "die ganz phantastische Auseinandersetzung über den Sehgeist so langatmig" (p. 21), which they find so unnecessary and extravagant that they paraphrase and epitomize most of Ḥunayn's section on visual pneuma rather than translate it (pp. 27-28), while translating in full the final section, "on the conditions of vision."

[84] Charles Mayo Goss, transl., "On Movement of Muscles by Galen of Pergamon," *American Journal of Anatomy,* 123 (1968): 1. For Ḥunayn's translation of this work into Syriac see Ḥunayn, *Galen-Übersetzungen,* p. 20, no. 39.

[85] Goss transl., "On Movement of Muscles," p. 3 (*De motu musculorum* I, 1; ed. Kühn, IV, 372): "Through the third conduit [the nerves (the prior conduits are arteries and veins)], that from the great source [the brain], it [a part of the body] becomes not simply a living thing but something in addition to a vegetative being by acquiring sensation and the power of voluntary motion, attributes by which the animal is differentiated from the non-animal. Through these powers the muscle has become an instrument of the brain (*psychikon organon*) exactly as it has become a natural or living one (*physikon*) through the arteries and veins, for the motions of the arteries and veins are simply living or natural and without impulse, but those of the muscles are voluntary and by impulse." Galen here seems to describe the realms of (a) sensation and movement (*psyche*) and (b) nutrition and growth (*physis*) similarly to the conceptions of the Stoic Chrysippus (ca. 280-207 B.C.); for Chrysippus see Hahm, *Stoic Cosmology,* p. 163.

> . . . Now, the pneuma existent in the ventricles of the brain does not remain long in these ventricles; from it the power of perception and the power of movement proceed into all the sensitive organs and into the limbs which are capable of voluntary movement. . . . The accession of perception and movement by means of this pneuma into the sensitive and movable organs must take place exclusively in the following ways: either so that its power [only] penetrates into the nerves, while its substance remains unchanged in the ventricles of the brain, just as the light of the sun[86] penetrates into the air when it begins to transmit its qualities to the air, until it reaches all the parts of it, but the substance of the sun remains and does not perish or change its place; or so that the substance of the pneuma itself flows into the nerves. And this too is possible in two ways: either (a) the substance of the pneuma runs along the nerve until it reaches the sensitive or movable organ, or (b) its substance flows into the nerve for a certain distance, effects a considerable change in it and then stops. And from this alteration that[87] arises which continues [on its way] in the nerves until reaching the organs. For perception and voluntary motion are of this pattern. They exist by means of the passage of this psychic pneuma and the communication (*wuṣūl*), in the nerves from the brain, of what[88] arises from it with the sensitive and movable organs.[89]

Ḥunayn's display here of some details of his (and *perhaps* Galen's) pneumatical doctrine helps to simplify our understanding of the various means of neural transmission in sensation and movement. With regard to the sense of sight Ḥunayn's section on visual pneuma is no more than an epitome of Galen's *On the Doctrines of Hippocrates and Plato*, Book 7, chapter 4. But Ḥunayn offers more than this by emphasizing (as Galen does not) the relationship of sense and motor nerves. Once we see this, we can then draw on Galen for fuller discussion of certain details. In doing this we must realize that we are following Ḥunayn, not Galen. Ḥunayn offers in one text both a synthesis and an extrapolation of Galenic texts that is nowhere justified by Galen. The most we can say about Galen is that he achieved a systematic doctrine of sight. His teachings on the other senses have certain affiliations with the doctrine of sight, but there is no satisfactory ground for asserting an explicit or even implicit completed doctrine of sensation in his writings.[90] It is just this sort of completion of a "Galenic" doctrine that Ḥunayn performs.

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[86] While Meyerhof's translation here reads "brain" (Ḥunayn, p. 28), his edition of the text has *shams*, or "sun" (Arabic p. 99, 1. 7).

[87] Meyerhof (Ḥunayn, p. 28) here interpolates "the substance" after "that." This addition to the text creates a meaning opposite that intended by Ḥunayn. Here and in the following final sentences I have changed Meyerhof's translation.

[88] Here again (Ḥunayn, p. 28) Meyerhof adds "substance" after "that," producing the same shift (and confusion) of meaning.

[89] Ḥunayn, pp. 27–29.

[90] This I maintain in pointed contradiction to the attempts of Siegel, *Sense Perception*, pp. 40–116, to find Galenic doctrines of sensation. Siegel transforms Galen's implications into explications and produces some very unfortunate notions, e.g., the notion that *dynamis* is a king of *pneuma* (pp. 47, n. 115; 71). A more serious student than I of Galen on sensation might also ask why Siegel consistently refers to Kühn's edition rather than the superior Müller edition for texts of the *De placitis Hippocratis et Platonis* (and see now De Lacy's edition, which supersedes that of Müller).

The Galenic source clearly states three options for how the pneuma effects something at a distance: (1) local pneuma in the nerves is affected by pneuma flowing along the nerves "from the source of power;" (2) pneuma flows continuously from the brain to the part; (3) via the neura there is a "qualitative change of continuous parts . . . , [which is a] flow . . . by virtue of some power without substance."[91] This third option is immediately explained.

> The transmission of qualities to continuous bodies by alteration *they* (my italics) call a flow of power (*dynamis*), as when in the surrounding air some transmission of quality sets out from the light of the sun and reaches every part of the air, while the actual substance of the sun remains in its place.[92]

Here Galen fails to give unequivocal identification of the explanation as his own, referring to an unnamed "they," yet he offers no alternative and adds that he has already used this account in his own work *On Demonstration* (now lost).[93] One further quotation gives the fullest commitment offered by Galen on this difficult matter. He says, in order to distinguish power from pneuma,

> It is not possible to state readily whether power flows in this way from the brain to the limbs through the nerves, or the substance of the pneuma reaches all the way to the perceiving and moving members, or it falls upon the nerves for a certain distance so as to alter them violently, and the alteration is then transmitted as far as the moving members. I showed in my work *On Demonstration* that something of that [last] kind happens also in visual perception.[94]

At this point in *De placitis* Galen shifts to a consideration of vision alone, about which he feels certain. About the other senses he is less certain and leaves the reader with alternatives and a sense of what is likely, but not a complete doctrine. A stronger suggestion, approaching full commitment, appears in *De motu musculorum* I, 1, when he says, "Thus in the nerves, some great power resides flowing to them [the muscles] from the great source. The power is not inherent in the nerves. . . . The nerves, being *analogous* (my italics) to conduits, carry power (*dynamis*) to the muscles from some format of the brain."[95] At this point Ḥunayn takes command of the Galenic line of thought and explicitly generalizes to all the senses, conveniently ignoring Galen's explanation of the sense of smell as the one sense organ which does not exist apart from the brain.[96] For Ḥunayn the hypothetical possibilities offered by Galen are the realities from which to choose. As Ḥunayn has already said before and will reiterate again, it is the substance of pneuma which passes by way of the nerves for vision, but it is only the "force" of the pneuma which passes along the neura for the other senses.[97] He opts for the last Galenic alternative to explain all sensory nerve passages other than sight, that is, the substance of pneuma penetrates somewhat into the nerves and therein creates a "force" (an "alteration," in Galen's terms)[98] which proceeds the rest of the way to the sense organ and gives sensation. After this categorization of the various means of psychic pneuma for effecting sensation and movement, Ḥunayn turns to the visual pneuma alone.

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[91] *De placitis* VII, 4, De Lacy, p. 448, ll. 13–14.

[92] Ibid. p. 448, 14–18.

[93] On Galen's *De demonstratione* see Iwan P. E. von Müller, *Über Galens Werk vom wissenschaftlichen Beweis*, Königlich Bayerische Akademie der Wissenschaften, Philosophisch-Philologische Klasse, Abhandlungen. Bd. 20, Heft 7 (1895): 403–478.

[94] *De placitis* VII, 4, De Lacy, p. 448, ll. 19–26. Again and again Galen distinguishes the transmission of "power" (*dynamis*) by a continuum from the passage of a substance, such as pneuma; e.g., De Lacy, p. 452, ll. 22–28. While Galen's meaning for *dynamis* is not distinctive, as is his notion of visual pneuma, he does consistently use *dynamis* and not, for instance, *energeia*. On the simplest differences between such terms, see Galen, *On The Natural Faculties*, transl. Arthur J. Brock (London: Heinemann, 1916; repr. 1963), pp. xxix–xxx. The simple sense of *dynamis* in *On the Natural Faculties (Dynameon)* becomes narrower and more technical in *De placitis*; in the former work neither pneuma nor sensation is of special concern or treated in any detail at all. It is to be noted that in *Natural Faculties* I, 2 (transl. Brock, p. 13), Galen conceives of *dynamis* as cause (*aitia*) of activity (*energeia*).

While following Galen's *De placitis* closely in sequence of topics and in general doctrine, Ḥunayn continues to show his readers the mind of a Galenist at work, organizing more tightly and modifying arguments in order to eliminate the ambiguities and uncertainties of his model. While omitting Galen's evidence for a hollow optic nerve by anatomical dissection,[99] Ḥunayn adds a pseudo-quantitative note to the Galenic account of the visual pneuma flowing to the eyes. The substance of the visual pneuma, not just its power (or "force"),

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[95] Kühn IV, 371; transl. Goss, p. 2.

[96] *De instrumento odoratus* 4; Kühn II, 867, 869; Kollesch, pp. 44, 46; transl. Wright, pp. 5, 6: the sense of smell arises in the ventricles of the brain, and there is no suggestion of a "power" being sent via neura to the nose. See Ḥunayn, *Galen-Übersetzungen*, p. 22, no. 48, for Ḥunayn's translation of this work into Syriac.

[97] Ḥunayn, pp. 22, 29. Ḥunayn actually says (p. 29) "The organ to which the nerve is joined receives the *force* (my emphasis) of the latter in its whole body and becomes thereby sensible and perceives the touch of all [the things] which it meets. Therefore we see that the flesh has distinct perceptive power and feels the object which it meets with the sense of touch which is in it and which it receives from the source." Lindberg, *Theories*, p. 231, n. 39, construes this passage to mean the following, which he derives from an interpretation of the corresponding passage in the medieval Latin version: "the instrument [i.e., the eye (Lindberg's addition)] is changed into the nature of the nerve that is conjoined to it and thereby becomes sensitive. It is therefore again evident that flesh perceives because of the power of vision (*sic*!) existing in it, which is bestowed on it by the nerve." Ḥunayn takes pains to distinguish the transmission of "force" alone in the other nerves from the transmission of a substance in the optic nerve. The medieval Latin version, which I would not generally recommend as an improvement on the Arabic, definitely refers to the sense of touch at this point, not to the sense of vision; the part translated by Lindberg is given in italics; "Sensus vero per quem membrarem sentiendam sentiunt, non ad cerebrum venit ut ab eo sentiatur vel discernatur. Hoc enim si esset, nullo modo percussio vel sensibilis membri motio ab eo sentiretur, ac si sensu membrum careat. Nervus nim non est aliud nisi pars cerebri, sicut rami arboris ab ejus radice procedentes, *nam membrum in naturam nervi mutatur sibi conjuncti, unde fite sensibile. Palam ergo est quia iterum caro sentit propter vim sensus in ea existentem que sibi a nervo tributa.*" For the Latin text see Pierre Pansier (ed.), *Collectio ophtalmologica veterum auctorum* (Paris: Baillière, 1909-1933), II, fasc. 7, p. 176: about the treatise, *Constantini de oculis*, we can say, contra Julius Hirschberg, that it might best be considered either a close paraphrase or a loose translation of Ḥunayn's *Ten Treatises*, because of its variations from the text established by Meyerhof (see Pansier, p. 166). Note, among other things, that the Latin version has no term clearly denoting the "force" in Ḥunayn's text here. But the word "virtus" does appear as an adequate equivalent at another point (Pansier p. 174; compare Ḥunayn, p. 22). Other variations between the Arabic and Latin texts are noted below, n. 145.

[98] Galen (*De placitis* VII, 4; De Lacy, p. 448, l. 23) speaks of this alteration taking place "sharply," or "violently" (*sphodros*).

> . . . reaches them [the eyes] by way of the two canals piercing the optic nerves, the quantity of it reaching them being [just] the quantity necessary to fulfill the function of vision. An argument that the substance of this pneuma reaches the eyes itself and in this quantity is to be found in the form and nature of the optic nerves, that they have been created hollow, as we described before.[100]

This quantity, of course, is not measured and is defined only teleologically—the amount of pneuma is the amount needed to do the job. Ḥunayn proceeds to follow Galen closely (almost verbatim) in describing and reasoning about the flow of visual pneuma into the region between lens and cornea. The argument is materialistic and mechanical, though not quantitative. Remembering that this space is already filled with aqueous humor, we are told to conceive that

> . . . when one shuts one eye, the pupil of the other one becomes enlarged, and when the closed eye is opened the pupillary hole of the other eye returns to normal size. This a clear proof that this enlargement is caused by the uvea when it is distended by the filling up of the place behind and inside it. So that compels it [the uvea] to enlarge the opening which is in it. It is not possible that this enlargement has any other cause than this. Similarly, it is not possible that the rapidity of the filling of that place and the rapidity of its emptying occur from the action of the humour flowing down to that place and filling it and then leaving it again and returning.[101] Rather, it is accomplished from the action of the substance (*jawhar*) of the pneuma alone, as is necessarily explained by analogy.[102]

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[99] *De placitis* VII, 4; De Lacy, p. 450, ll. 2–9.

[100] Ḥunayn, p. 29.

[101] At this point Meyerhof inserts a clause, "for no analogous physiological action takes place," in his translation (p. 30, ll. 3–4), even though there is no clause of *any* sort here in the Arabic text (p. 101, ll. 3–4); I assume Meyerhof takes this clause from the last sentence in the paragraph (Arabic p. 101, ll. 4–5), which does not seem to justify his interpretation and which I have replaced by the phrase at the end of the translated paragraph. The reader will notice that I have modified words and phrasings from Meyerhof's translation of this paragraph; I follow suggestions by Emilie Savage-Smith on this.

[102] From here on Ḥunayn follows Galen closely and sometimes verbatim. It appears that such a paragraph as this may have been conceived as a translation of Galen's text, especially when we consider both (1) the possible difficulties in the Greek MS. tradition and (2) the special interest and sense of personal understanding (and perhaps improvement?) brought by Ḥunayn to the text of bk. 7 of *De placitis* (see Ḥunayn, *Galen-Übersetzungen*, pp. 21–22, no. 46). A translation of Galen's text into English can be compared: "That a pneuma is carried through these passages to the eyes you learn from the structure and also from the fact that when one of the eyes is closed the pupil of the other is enlarged, and when it is reopened the pupil of the other quickly returns to its natural size. It is not difficult to perceive that when the grape-like tunic [uvea] is distended by some substance that fills the space inside it, it is necessary for the perforation in the pupil to be widened, as there is no other possibility, and that the speed of emptying and filling is not the work of some fluid flowing in, but only of an airy substance." See DeLacy's edition, p. 451, ll. 11–12; a student of Greek will note, for example, that lines 17–18, p. 450, could be retranslated to look much more like the wording given from Ḥunayn.

The visual pneuma is understood as a highly fluid substance which penetrates the forward region of the eye, mixes with the preexisting humor there, *fills* the area, and distends it so as to require the dilation of the pupil. A reader may ask how a space which is full of material (aqueous humor) already can be *filled and emptied* by another material. The answer appears to come from the implied source of the Galenic conception here, the Stoic doctrine of pneuma,[103] revised by Galen to fit a more simply mechanical explanation. Insofar as the space is filled with a humor, it is filled, but insofar as that humor is watery, not spirit-like, it is penetrable by and mixable with pneuma without distension. When the space is filled with pneuma, it is then absolutely filled, and further infusion of pneuma will cause expansion of the containing fabric. The expansion which takes place—an expansion purposefully designed to relieve this stress—is the dilation of the pupil. The entrance and retreat of the pneumatic substance is extremely rapid, which shows that the effect comes about from a very subtle, viz. pneumatic, substance rather than a slower-moving humid substance. This seems to be Galen's implied line of reasoning (followed by Ḥunayn), and it's non-quantitative aspect as well as its vocabulary follow Stoic principles.

Ḥunayn next advances a strong argument based upon the foregoing explanation. He imagines the mechanics of the visual pneuma in a person with cataract in one eye. The person may shut *either* eye, and the other eye, he says, may dilate or not. Dilation is "proof that the power of vision has been left normal,"[104] for the pneuma now flows from the optic chiasma solely into the open eye. If this eye, with or without cataract, does not dilate, "then the power of his vision is destroyed at its source."[105] He reasons that "the substance of the pneuma does not reach the eye and does not fill the place behind the uvea inside, and the uvea is not distended by it nor is its hole enlarged."[106] The conclusion is, "If there is such a condition in them, those are right who say that the optic nerve . . . is obstructed, and this is the opinion of skilled physicians whose perspicacity is very acute."[107] The character of Ḥunayn's argument is notable. What he offers is a diagnostic test for the effectiveness of the visual faculty, not the eye as a separate organ, in terms of the activity of a part of the eye. Since this activity (dilation) is conceived in the mechanical form already explained, the activity observed is considered a test for the activity (flow) of an unobserved part (visual pneuma), whose positive or null effect is further explained mechanically (obstruction of passage) rather than as a weakness or disappearance of the visual pneuma itself. Ḥunayn's use of the diagnostic test is not to provide practical information but rather to prove the flow of an actual substance instead of a "power" alone. We may therefore conclude that he is arguing in a circle. Does his model, Galen, do the same?

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[103] For Stoic pneuma and its mixture see Sambursky, *Physics*, p. 16, and Lutz Bloos, *Probleme der stoischen Physik* (Hamburg: Buske, 1973), pp. 57–64, who follows Sambursky's broader lines of interpretation but significantly revises specific interpretations of Stoic cosmology. Compare Galen, *Usefulness*, X. 5, transl. May, p. 476, where the pneuma between cornea and lens is described as being under pressure or tension.

[104] Ḥunayn, p. 30.

[105] Ibid.

[106] Ibid.

[107] Ibid.

Galen's argument, given in almost the same terms, is couched in subtle and important conditionals, which Ḥunayn obliterates. Most significant is Galen's statement that the non-dilation of a pupil makes it look "as if"[108] the pneuma is no longer reaching the uvea. Immediately he adds that "many distinguished physicians, therefore, have said *with good reason* (my emphasis) that in such persons the passages of the optic nerves have been stopped up."[109] The whole tone of Galen's argument is one of persuasion, while Ḥunayn speaks with an air of certitude, pursuing his larger goal through a series of subordinate conclusions. Where Galen is satisfied to leave a margin of doubt,[110] Ḥunayn comes forth with certainty, lest his construction of a larger picture (his microcosm) falter.[111]

To close his discourse on the visual pneuma, Ḥunayn argues strongly against the notion that nerves other than the optic nerves are hollow and permit passage of a substance. However, this leads him to the possible objection that there is no necessity for hollow optic nerves, if other, non-hollow nerves adequately convey "the necessary power." This objection gives him opportunity to conclude with a description of the visual pneuma which will serve to explain its action in the process of vision itself.

> . . . the penetration of solid objects by the faculties is a weak penetration and especially when the receiving object is extremely large or extremely hard or can only be transformed by the output of an excessive amount of energy. Should, however, the substance sent from the source be a substance excessively fine and strike an object violently after travelling a certain distance, then the alteration is greater. For the penetration of power into an object is the penetration by the alteration caused by its substance, as is likewise the penetration of the air by the sunlight. And the pneuma that reaches the eyes fares in the same way, in that it joins the air immediately after leaving the eye and transforms it according to its own particular nature.[112]

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[108] *De placitis* VII, 4; De Lacy p. 451, l. 15, p. 450, l. 28. I accept responsibility for using this and the next translation in extremely exact senses.

[109] Ibid., p. 450, l. 30-31; p. 451, l. 16.

[110] Not only does Galen leave a margin of doubt, but he also proceeds to add a good bit more observational evidence (of a casual sort) about loss of sight and pupil dilation in various animals. See ibid., pp. 450-452.

[111] Ḥunayn also places an "if" in his account, which has been mentioned already: "If there is such a condition in them. . . ." See above at n. 107. However, his "if" conveys not a sense of uncertainty but rather a specification of the condition, viz. a statement that this only happens *when* such a condition occurs.

[112] Ḥunayn, p. 31. Compare Galen again (*De placitis*, VII, 4, De Lacy, p. 452, ll. 25-28) for his version of this process includes the following: "Thus *it is likely* (my emphasis) that in this way the pneuma coming into the eyes is united at the first impact with the surrounding air and alters the air to its own peculiar nature but does not itself extend out to the farthest distance."

The process summarized here becomes the heart of the final section, on vision and its conditions, of tract 3 of the *Ten Treatises*. The hollow optic nerves are required in order to allow such a completion of vision, and the luminous nature of the visual pneuma itself accounts for the specific means by which the pneumatic interaction with the outside, airy medium occurs. All the preceding information and arguments have come to a point here. The elaboration of that point is Ḥunayn's final and ultimate concern.

C. AIR, PNEUMA, AND LIGHT

The final section of tract 3 develops through three stages. Initially, a set of alternatives (three, of course!) is posed, in scholastic fashion, to explain how we might see the object of vision, and responses to these alternatives follow. The last is Ḥunayn's preferred choice, and his supportive response takes the form of an extended discussion of the interaction of the outside air both with visual pneuma and with exterior light, showing the interrelationships of these three elements in vision. The second stage proceeds through an elaborate comparison of vision with the other senses in terms of their respective elements to show (1) how vision is either like or unlike each of the others, (2) where vision belongs in our understanding of the senses of man and their place in the microcosm. The final stage of tract 3 offers a summation, concluding that the microcosmology of sense perception, conceived in terms of interacting elemental media, makes the third option, in the set of alternatives initially posed, the only acceptable and satisfying explanation of seeing an object. Stages two and three are subordinate to stage one, for the last two stages provide the larger, cosmological framework for accepting the preferred theory of vision.

How is an object out there perceived by a viewer, whose eye and visual pneuma are quite separate and at a distance from the object? To answer this question Ḥunayn considers three alternatives: (1) intromission, (2) extramission, (3) pneumatic medium. Each possible answer is conceived in terms of tactility,[113] and these terms, often implicit, give much of the limiting framework for understanding vision. The first two possibilities are rejected, leaving the field open for the third.

To set up the intromission theory of vision—the object sends out "something from itself to us by which it indicates its presence so that we know what it is"[114]—Ḥunayn begins by specifying, "all people acknowledge and agree that we see only by the hole which is in the pupil."[115] The subsequent argument against intromission has two parts. The first part takes the approach that what is necessary for vision would not happen in the situation hypothesized. That is, it is assumed that we estimate such properties as the size of a seen object, for example a mountain, by means of the visual pneuma. Given the intromission theory, it will be necessary for the "something" or "power" or "form" to come from the object through the hole in the eye in order that the visual pneuma might estimate size.

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[113] On the tactile, as opposed to perspective, bases of Euclidean geometry and optics, see William M. Ivins, Jr., *Art and Geometry: A Study in Space Intuitions* (Cambridge, Mass.: Harvard U.P., 1946), esp. chs. 1, 3. The Greek tendency to extend tactile-muscular descriptions to a wide variety of physical objects, including theoretical objects, is remarked by Ivins (p. 6), who also notes, following Bertrand Russell, the modern emergence of sight-physics to a position of dominance over tactile-muscular description (p. 104, n. 12).

[114] Ḥunayn, p. 31.

[115] Ibid., p. 32.

According to the requirements of the situation, any such power or form, coming in its shape or outline *to*, not through, the hole of the eye for perception, would correspond to (be analogous to, be indistinguishable from) the largest possible object, because of the hole. Using the example of a mountain, Ḥunayn says, "the shape of its forms or the outline of the measure of its volume [thereby] corresponds to the volume of the greatest possible mountains."[116] Thus the presence of something *at* the eyehole cannot properly explain our vision. Proceeding to the second part of his rejection of the intromission theory, Ḥunayn considers the possible entry of the power or form *into* the eye so that an estimate of the size of the object might be ascertained by the visual pneuma. This would require the entry of the "complete form or outline . . . into the eye of the beholder at the same moment."[117] Yet such an entry into the eyes is "something which reason does not comprehend and of which nobody has ever heard,"[118] he says. The reasoning becomes materialistic and vaguely (but not strictly) quantitative. If we suppose that 10,000 people look—he does not specify whether simultaneously or successively[119]—at the object, then we must further suppose that a form or outline "enter completely into" every one of them, thereby (implicitly) exhausting the matter of the object, since the form would not return from inside the eye to the object. Again, the form must actually be within the eye for the visual pneuma to perceive size.[120] Such perception we can best understand as para-tactile: the visual pneuma grasps, surrounds, and is impressed with the form of the object. As a result, the intromission theory of vision[121] is for Ḥunayn "among the untenable hypotheses."[122]

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[116] Ibid., Ḥunayn either misunderstands or else recasts the first part of Galen's argument. Galen claims, "We see through the perforation at the pupil; if this perforation waited for some portion or power or image or quality of the external bodies underlying (our perception) to come to it, we would not discern the size of the object seen, which might be, for example, a very large mountain. An image the size of the mountain would have come from the mountain and entered our eyes, which is utterly absurd," De placitis, VII, 5; De Lacy, pp. 452, l. 34-453, l. 3. Ḥunayn's wording seems to me to intend an improvement on Galen, making the argument both different and more a matter of reasoning, less a simple assertion as found in Galen. The comparable statement by Ḥunayn reads, "I say: all people acknowledge and agree that we see only by the hole which is in the pupil. Now, if this hole had to wait until something coming from the seen object reached it, or a power emanating from it, or a form, an outline or a quality, as some people maintain, we should not know, if looking at an object, either its extent or its volume, whether it were, for example, a very high mountain, or the like; and this because the shape of its forms or the outline of the measure of its volume corresponds to the volume of the greatest possible mountains." At Ḥunayn, p. 32, n. 1, Meyerhof supposes that Galen and Ḥunayn have the same argument in mind.

[117] Ibid., p. 32.

[118] Ibid.

[119] Galen, however, makes it clear that the argument is conceived to require simultaneity; see *De placitis*, VII, 5; De Lacy, p. 454, ll. 3-4. Ḥunayn presumably has the same idea in mind, but he places the qualifying phrase, "at the same moment," in the previous sentence, which refers to a single observer rather than to all observers; see above at n. 117.

The extramission theory—"the faculty of perception goes from us to it [the object] and we recognise what it is through this medium"[123]—is dismissed completely and yet, curiously, is not discussed. Ḥunayn says only, "Concerning the second theory I say: It is not possible that the visual pneuma extends over all this space until it spreads round the seen body and encircles it entirely."[124] That Ḥunayn remains Galenic but improves upon and systematizes the text of Galen is evident when we realize that Galen offers only two alternative theories. He says that either the object sends something to us, or a sensory power (*dynamis*) passes from us to the object.[125] Comparing Galen and Ḥunayn we learn that Galen's second option is Ḥunayn's third. Ḥunayn's second hypothesis is drawn from the last sentence in Galen's paragraph on the intromission theory. Obviously extending the materialistic thinking (a mountain with 10,000 observers) just completed, Galen briefly notes in passing that "the optic pneuma cannot extend itself and acquire such a stream as to envelop the whole object being viewed, for this is comparable to the Stoic drop that mixes with the whole sea."[126] Galen does not agree with the general Stoic theory of mixture (perhaps does not even understand it) and, conceives of the visual pneuma in terms more thoroughly materialistic than did the Stoics. Any extension of the pneuma itself through the whole medium between observer and observed is out of the question. Ḥunayn bypasses the reference to Stoics and simply asserts in scholastic fashion the impossibility of the extramission theory. There is, however, an implied basis for the assertion. Because he is continuously building a unified theory of vision—the whole structure and reasoning of tracts 1-3 show this—we can recall what Ḥunayn has already said about the nature of the visual pneuma to supply a rationale for rejecting extramission. The visual pneuma is material and requires a canal, but there is no canal beyond the eye. The pneuma is subtle and in need of protection, but there is no protection beyond the eye. Given such preexisting reasons, Ḥunayn can dismiss the impossible theory and also ignore Galen's reason for dismissing it. Galen speaks in somewhat quantitative terms, rejecting the Stoic theory of mixture. Ḥunayn prefers to argue from the nature of the visual pneuma, not from quantitative terms nor from the theories about unending dispersion. Here we see the most likely reason for his separation of this argument to a distinct heading. Where Galen rejects extramission for the same kind of quantitative reasoning as he applies to intromission, Ḥunayn sees a very different basis for rejection and conceives a second, separate theory.

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[120] Galen makes the perception of size along with shape and color the characteristic perceptibles of vision at this point in *De placitis* (De Lacy, p. 460, ll. 11-13): "Therefore it [vision] alone can discern along with the color of the thing seen its size and shape, which no other sense can perceive, except that sometimes touch does so incidentally." However, Galen complicates the issue by specifying elsewhere other properties perceived by vision (*De placitis*, VII, 6: motion, number; VII, 7: distance; *De usu partium*, XVI, 3: motion, position, distance). Ḥunayn takes up these additional properties later, and he includes position, distance, and relative motion; see below at nn. 148-149. He attributes these perceptibles to touch as well.

[121] Lindberg, *Theories*, p. 37, reasonably considers Ḥunayn's dismissal of intromission to be a rejection of both the atomistic and the Aristotelian versions of sending something from object to viewer. However, Ḥunayn, following Galen, does not refer to any theory by name, presumably because Galen later finds it useful to point out the limitations of each named theory (Stoic, Epicurean, Aristotelian) in *De placitis*, VII, 7 (De Lacy, p. 474, ll. 8-29), rather than totally dismiss each. What Ḥunayn explicitly rejects here is a general type of theory, not a specific theory.

[122] Ḥunayn, p. 32.

[123] Ibid.

[124] Ibid.

[125] *De placitis*, VII, 5; De Lacy, p. 452, ll. 31-33.

[126] Ibid., p. 454, ll. 4-7. Galen's reference to "the Stoic drop" is explained by Sambursky, *Physics*, p. 13, who notes the relevance of this Stoic theory of extremely dilute mixtures to pneuma. Sambursky quotes Chrysippus via Plutarch as saying, "There is nothing to prevent one drop of wine from mixing with the whole sea." On the Stoic (esp. Chrysippus') theory of pneumatic hexis, see Hahm, *Origins*, pp. 165-166, 169. More generally, see Bloos, *Probleme*, pp. 65-73 (*tonos*), 74-89 (continuum).

The third theory, vision by means of a pneumatic medium, is initially phrased, "by there being another thing with us and with it intermediate between us and [the object], so that we learn what it is."[127] To support this option Ḥunayn argues in three stages. First there is an elaborate discussion of the illuminated air as medium between the object and the visual pneuma. He develops the discussion in both directions. That is, he considers the changes and relationships of successive entities, proceeding from the object through the medium to the visual pneuma and also from the brain through the optic nerve (and its visual pneuma) to the external medium. The establishment of a two-way interaction along the path of vision prepares the way for more detailed description of the qualities and capacities of the connected visual media.[128] The succeeding stage deals with the properties of things which are perceived by sight, comparing those properties with the properties perceived by other senses, and noting the analogy of sight to touch with regard to properties perceived. The distinction of properties perceived is related to the distinct cosmic elements responsible for both the nature and the perceptions of each sense.[129] The final stage of the argument is a summation of the nature and working of the luminous air and luminous pneuma, with the transformed air acting like an extension of the optic nerve and thereby bringing visual perception of properties such as the size of a distant object, which the first and second proposed theories (intromission and extramission) could not account for.[130]

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[127] Ḥunayn, p. 32.

[128] This first page of the argument covers pp. 33-35 of Meyerhof's translation.

[129] This second stage of the argument is found on pp. 35 (last paragraph)—38 (line 27) of Meyerhof's translation.

[130] This final stage of the argument appears on pp. 38-39 of Meyerhof's translation and concludes tract 3.

The explanation of the pneumatic theory of vision is the crisis (perhaps *krasis*?) point of the whole visual-theoretical portion (tracts 1–3) of Ḥunayn's *Ten Treatises*, and a number of interesting problems, mentioned disparately in earlier parts of this study, here emerge and intersect. We have to consider the following: (1) most obviously, the exact nature of the argument presented by Ḥunayn; (2) the relationship of Ḥunayn's argument to Galen's argument in *De placitis*, which Ḥunayn has obviously paralleled and drawn upon yet has modified significantly in various ways; (3) whether the argument is better understood as a series of distinct scientific problems or as a treatise on the microcosm, reflecting the macrocosm.

To establish the nature of Ḥunayn's argument we must consider the details in his three-stage discussion of the pneumatic medium. Stage one begins with the statement of a relationship: that the luminous air is to vision as the optic nerve is to the percipient body (air : vision :: nerve : body). This is meant to assist our understanding of the transmission process in seeing. The initial description of this process specifies,

> In the same manner in which the power of sunlight, when it reaches the upper layers of the air, penetrates the air through and through, likewise the substance of the light which reaches the eye by way of the optic nerves is of the substance of the [visual] pneuma. When it meets the air in the moment in which it goes forth from the pupil, it transforms it immediately it encounters it, and that which arises from the change runs through it [the air] for a very long distance. It is evident that such a thing can be imagined only if the air is perfectly connected and there is nothing dividing it. So the change in the air caused by the [action of the] visual pneuma penetrates the whole air; and we find the same true of the power of the sun.[131]

Essentially the argument here is that the action of the sunlight on the medium (air) is in certain ways identical to the action of the visual pneuma on the same medium. The medium is continuous; both visual pneuma and sunlight have effects as soon as they penetrate the boundaries of the medium; the effects are considered transformations of the medium; the transformations affect the whole medium at once, or in an instant.

Next Ḥunayn shows that the continuity of effect requires continuity of action, at least for the luminous effects of sun and visual pneuma. The transformation of air by sunlight immediately ceases beyond an opaque barrier placed in front of the sunlight.[132] Similarly, when the optic nerve is severed from the brain, there is no visual effect thereafter, for the visual pneuma itself (like the sunlight) is no longer present.[133] Only when the source (sun, brain) is connected to the pathway is the transformation effected, and when this happens the sunlight and the visual pneuma are said to "resemble and correspond to"[134] the transformed medium. More discursively Ḥunayn points out that such luminous transformations differ from transformations by heat and cold, which are relatively durable and do not require continuous connection with a source for the effect to continue for a long time.[135]

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[131] Ḥunayn, p. 33.

[132] Ibid.

[133] Ibid., pp. 33–34.

[134] Ibid., p. 34.

The distinctive nature of the optic nerves, transmitters of the visual pneuma, requires Ḥunayn to remind his readers that, whereas only the sense nerves among all nerves are created soft, among the sense nerves only the optic nerves are hollow and thereby contain the same refined pneuma as does the brain. This makes the optic nerves alone *almost* identical in nature with the brain. The optic nerve "is in one respect removed from the nature of the brain, which makes it necessary for its [the nerve's] power to be equally removed from it [the brain], *i.e.* for its faculty to be likewise different from that of the brain."[136] On the other hand,

> the two hollow nerves serving the sense of vision have in their nature more in common with the brain than all the other nerves. So you do not find the nature of the brain in any of the organs of the other senses, nor do you find in any one of them such a large quantity of the pneuma which is in the ventricles of the brain as you find in the eyes.[137]

The conclusion to this line of thought, also concluding stage one of Ḥunayn's larger argument, is a description of the relationship of the internal and external elements of vision. In a properly functioning brain and eye, the eye will "share the nature of the brain" because of the visual pneuma in both, and "the relation of the brain to the nerve proceeding from it is exactly the same as that of the eye to the air surrounding the human body."[138] Brain is to nerve (which equals the eye) as eye is to air (brain : nerve :: eye : air). Thus Ḥunayn argues for a qualitatively continuous path of transmission from brain to perceived object. The act of vision will be complete when both sun (sunlight) and brain (visual pneuma) act together to eradicate all barriers to direct and immediate transmission of sensation. The transformation of the air by sunlight and visual pneuma makes the air "in place of an instrument"[139] and so brings about sight. The mechanism of this transformation and the distinct properties of things thereby transmitted will provide the matter for the next, second stage of the argument.

Ḥunayn's argument so far on the pneumatic medium closely parallels Galen's, but tendencies already seen in earlier parts of Ḥunayn's *Ten Treatises* continue to appear. Ḥunayn paraphrases and compresses Galen's text,[140] characteristically omitting a whole section of material on the relationship of eye and brain and on the identical appearance of retina and brain as established by anatomical dissection.[141] Such omissions do not appear to be due to any presumable limitations in Ḥunayn's audience but rather to the purpose of his text. While Galen's arguments, both in *De usu partium* and in *De placitis Hippocratis et Platonis*, are discursive and aimed in many directions (against many opponents), Ḥunayn's arguments are subordinated to a single conception: the unified and hierarchical structure of the eye, whose functioning reflects both its own ordered structure and the order imposed on its parts by the cosmic elements of which the eye (and brain) are composed. Galen the philosophical controversialist may be compared to Ḥunayn the medical teacher. Where the former debates, the latter indoctrinates. Ḥunayn continues such modifications and compressions to the end of his argument on the pneumatic medium of vision.[142]

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[135] Ibid.

[136] Ibid.

[137] Ibid., p. 35.

[138] Ibid.

[139] Ibid.

[140] *De placitis*, VII, 5: De Lacy 454–460.

Stage two of the argument informs us on three points: (1) the properties which we perceive by vision, (2) the mechanism of transformation of the air into a pneumatic medium, (3) the specificity, for cosmological reasons, of the transformed medium to the properties transmitted. The longest section is the first, in which Ḥunayn makes use of a notorious analogy, advanced by the Stoics and rejected by Galen:[143]

> The first of the objects of visual perception and the most prominent of them all is the perception of colours, because colour is something which the eye perceives in a superior manner according to its nature; and the eye alone perceives it in contrast to all the other senses, and at the same time with the colour it also perceives the body which has that colour and recognises it, just as the sense of taste not only recognises the flavour but also, at the same time, the body in which the flavour is; the only difference being that the sense of taste and the other senses [must] wait until the perceived object comes to the human body in order that it may be perceived. But vision extends itself by means of the air until it reaches the coloured body. Therefore the sense of vision alone of all the senses is able to recognise not only the colour of a body but also its size and shape, and it recognises, moreover, its

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[141] Ibid., 458, 7-30.

[142] Ḥunayn's omissions and compressions, for the reasons already given, are quite drastic from here on. Although he continues to follow Galen's *De placitis*, he compresses to three pages the material from the latter part of *De placitis*, VII, 5 through VII, 7 (De Lacy pp. 460-474). Much, of course, is fully omitted. Meyerhof (Ḥunayn, p. 36, n. 1) suggests that from here on Ḥunayn may be following book 5 of Galen's now lost *De demonstratione*, since Ḥunayn possessed an incomplete copy of the work and translated it into Syriac. However, our knowledge of the contents of book 5, dealing with colors and shapes, depends almost totally upon Galen's *De placitis*, VII; see Müller's study, *Über . . . wissenschaftlichen Beweis*, pp. 465-467, incl. footnotes. The fact that Galen did not include in *De demonstratione* the long extracts that we find in *De placitis* gives some support to Meyerhof's supposition, but Ḥunayn's practice of omitting quotations and particular references would equally well explain what we find at this point in *Ten Treatises*. Ultimately, it appears that we can establish only similarities between the explanatory parts of *De demonstratione*, bk. 5, and *De placitis*, VII, 5-7; explanatory differences we cannot establish. Therefore I prefer to see Ḥunayn's basic source here as *De placitis*, which we can examine, rather than *De demonstratione*, which we cannot examine. Müller observes (ibid., p. 467) that Galen may have continued his discussion of vision on through Books 6-7, for we know nothing of their contents. For fragments of *De demonstratione* remaining in works of Al-Rāzi and extant in 3 MSS. see Sezgin, *Geschichte*, III, 77.

[143] *De placitis*, VII, 5, De Lacy, p. 460, l. 30; VII, 7, De Lacy, p. 474, ll. 8-12.

> situation and the intervening distance. Moreover it recognises its movement, and, although this recognition is not that of an absolute perception but the recognition of a relationship similar to perception, [nevertheless] no other sense is able to perceive these things with the exception of the sense of touch; for it [the touch] results either from deduction or from comparison with something which the individual has estimated by previous knowledge.
>
> The following is an example: If a person is walking in the dark and holds a stick in his hand and stretches it out full length before him, and the stick encounters an object which prevents it from advancing further, he knows immediately *by analogy* (my emphasis) that the object preventing the stick from advancing is a solid body which resists anything that comes up against it. What leads him to this judgement is that he knows from former experience that movement and walking in the air is without any obstacle, whilst movement and walking against a solid body is not possible. It is the same with vision: when it falls on a fully polished and bright body, it returns reflected to the pupil from which it went forth, with reflection of the images and their return at the same angles as those at which the visual rays proceeded from the eyes. Therefore, when we look into a mirror or at another polished and bright body, we sometimes see ourselves and sometimes others who are at our right or left or behind us.[144]

With regard to the analogy, first of all, what does the text show us? The analogy is not between touch and vision but rather between present and remembered past.[145] The person's knowledge by analogy is called a judgment, based on former experience, exemplifying the second of two ways in which the sense of touch brings perception. Ḥunayn also makes it clear why he includes the analogy in his mention of experiences of images reflected from the side or behind the viewer. We know, not by deduction but by comparison (analogy) with remembered experience, that the figures seen by means of reflected images actually exist to our right or our left or behind us. Reflection does for vision what the stick does for the unseeing person's sense of touch. However, the relationship of stick to touch is not identical with the relationship of reflection to vision. Nor is the stick meant to be compared with the mirror. The only *strict* comparison to be found in the paragraph is that between the two estimations based on previous knowledge.

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[144] Ḥunayn, pp. 35–37. Ḥunayn continues, offering as an example of reflection the image one man sees of himself in the eye of another man; the reflection occurs, according to Ḥunayn, on the surface of the arachnoid membrane, because it is "more polished and shining than all other bright, luminous and polished bodies." Meyerhof (Ḥunayn, p. 37, n. 1) points out that this statement is incorrect, since the primary reflection is from the cornea. More to the point, however, is the observation that Galen made the same claim for the arachnoid, saying, "And it is in this that we observe our image, just as when we see it in a mirror, when we look into the eye of any person who is close to us"; see Galen, *On Anatomical Procedures*, X, 3 (transl. Duckworth, Lyons, Towers, p. 40); similarly Galen, *Usefulness*, X, 6, transl. May, p. 479.

[145] Lindberg, *Theories*, p. 39, sees a direct analogy between stick and air medium. His quotation from Ḥunayn, omitting part of the text, shows how this understanding is reached; "If a person is walking in the dark and holds a stick in his hand and stretches it out full length before him, and the stick encounters an object which prevents it from advancing further, he knows immediately by analogy that the object preventing the stick from advancing is a solid body which resists anything that comes up against it. . . . It is the same with vision"; see ibid., p. 39, from Ḥunayn, p. 36. Lindberg recognizes that the analogy as he understands it could appear to be quite mechanistic, which would not fit with Ḥunayn's view of the transformed air medium, which is sensate. Lindberg warns, "this analogy has connotations that I do not believe Ḥunain intended, for it may seem to imply that the air is a passive (and inanimate) medium through which pressures or impressions are returned to the eye. In short, it is likely to have, for us, the connotations of Cartesian mechanism, whereas in fact Ḥunain intended nothing of the kind"; see Lindberg, *Theories*, p. 39. And finally, "Galen had rejected the walking-stick analogy precisely because of its mechanistic connotations . . ., and it is puzzling that Ḥunain, whose theory of vision does not differ from Galen's, would revive it"; see ibid., p. 231, n. 38. There is a remarkable difference between Ḥunayn's statement on the relationship of touch and vision and the statement appearing in Constantine the African's *De oculis* (see above n. 97 for other differences); the Latin version of Ḥunayn's treatise translates the middle portion of the relevant text (above at n. 144) as follows: "Hac de causa solus visus sentit formam corporis et quantitatem, et motum etiam cum ejus colore. Montum rationabiliter, non sensualiter sentit: que nullus ceterorum habet nisi tactus *accidentaliter* (my emphasis). Verbi gratia si quis per tenebras ambulaverit et fustem in manu duxerit, eo amplius non posse

The second paragraph provides examples for two senses, those of touch and vision. The "analogy" indicated does not lead to any connection between touch and vision themselves. Yet there is a relationship between touch and vision, and it appears in the first of the two paragraphs, explaining why these two senses are discussed together. Ḥunayn's conception of vision is fully understood only when placed together with his ideas on the other senses. The conditions of vision are conditions in harmony with the conditions for the operation of other senses. The sense of taste, for example, can perceive both flavor and the body possessing the flavor; likewise sight perceives color and its body.[146] But vision stands above taste and the other senses in that all senses except vision require contact between perceived object and human body.[147] Does this realization separate vision radically from the other senses? Not for Ḥunayn, who has already mentioned a similarity between vision and taste and who now proceeds to remind us of similarities between vision and touch. Touch, like vision, recognizes size, shape, location, distance, and motion.[148] Although touch is

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se penetrare sentiet. Cognoscet enim solidum corpus ei repugnare, quod non posset scire, *nisi in sua memoria habetur* (my emphasis) quia possible est per aerem ambulare, eumque penetrare, sed per solidum corpus hec posse fieri impossible est. Visus autem iterum alteram habet proprietatem, quia incidens super. . . ." (ed. Pansier, p. 179). The Latin omits the perception by vision of shape and distance; the use of *accidentaliter* for perception of motion by touch implies a different sort of understanding, especially because Ḥunayn's fuller explanation is omitted by Constantine; where Ḥunayn uses the walking-stick analogy to show a similarity between sight and touch (the use of memory in connection with each), Constantine uses the same comparison to emphasize the difference between sight and touch, saying that only sight perceives motion directly (pursuing this thought further in subsequent, unquoted sentences).

[146] Galen, *De placitis*, VII, 5 De Lacy, p. 460, ll. 7-8, makes exactly the same observation about taste perceiving flavor and body as sight perceives color and body.

[147] Again Galen, ibid., p. 460, ll. 8-11, makes the same point as Ḥunayn.

[148] Galen, ibid., p. 460, ll. 11-16, recognizes size, shape, position, and distance as properties discerned by sight. Later (*De placitis*, VII, 6, De Lacy, p. 466, ll. 26-28) he says that size, shape, motion, and number require not only sensations but reasoning and memory. Ḥunayn's version of this issue is to disregard the reclassifying of size and shape, already attributed unqualifiedly to sight in Galen's earlier passage, and to speak only of motion, not included earlier by Galen, as a property recognized through vision, "although this recognition is not that of an absolute perception." Such perceptions as that of motion are then said by Ḥunayn to result "either from deduction or from comparison," as happens with the sense of touch. Ḥunayn seems to have followed Galen rather closely but to have systematized more carefully. See above, n. 120.

unlike vision in requiring contact by the human body, touch is like vision (and unlike the other senses) in its ability to make judgments about size, shape, location, distance, and motion.[149] The perception by each sense adds something not available through the others, but each sense is modeled in some way on one or more of the others. What we learn, then, from the first of the two paragraphs given is that each sense (though smell and hearing are not mentioned at this point) is singular in some way but common in other ways.

In a brief paragraph, taken more or less verbatim from Galen, Ḥunayn gives us an account of the mechanism for the transformation of the air into a pneumatic medium, provided that sunlight (or another source of light) and visual pneuma are present.

> If vision alone of all the senses [is able to] perceive the moving objects by means of the air—as the blind man feels things with the stick—yea, first perceives the object of vision by its help, so that it [the air] is for the time being a homogeneous and coherent instrument of it [the vision]; and if vision alone is distinguished by this peculiarity and, moreover, sometimes sees the object by reflection of the images and their return to it [the vision], then necessity demands a lucid pneuma (*rūḥ nayyir*) in a large quantity which runs from the brain into the eye. When it has entered the eye and comes out of it, so that it meets the surrounding air, it strikes it as it were with the shock of collision, transforms it and renders it similar to itself.[150]

Here (not in the earlier passage) there is a direct comparison of touch and vision, insofar as each makes use of a medium which allows sensation of the *motion* of distant objects. With regard to the stick Ḥunayn says simply that the blind man *feels* by means of the stick.[151] The sensation of touch in its unanalyzed and human bodily meaning should be understood here. Feeling is clearly involved, and no suggestion occurs that the sense of touch is inanimately mechanical. Where stick and air are alike is where each is "homogeneous and coherent," the stick as instrument and the air as instrument. At this point the analogues part, for the stick is not changed by human touch in the way the air is changed by visual pneuma. The phenomenon of vision occurs when the "lucid pneuma" proceeds from brain to eye to surrounding air and makes it like itself. How are we to understand this? Despite the clause, "it strikes it as it were with the shock of a collision," there is no intimation of mechanical action here. The results of collision, we should realize, may be less events of motion and more events of pain or some other sensation. The extension of the "lucid pneuma" beyond the surface of the eye to some extent—a measurement of that extent is not discussed—belies any conception of rigid bodies, incompressible media, and mechanistic action.[152] The phrase "shock of collision" seems to mean that there is a notable and sudden event with striking consequence. The consequence, a transformation of the air, is pneumatic.

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[149] Likewise Galen, *De placitis*, VII, 5, De Lacy, p. 460, l. 12; VII, 6, De Lacy, p. 466, ll. 26-28.

[150] Ḥunayn p. 37. Compare Galen, *De placitis*, VII, 5, De Lacy p. 460, ll. 28-33, where the text runs, "If then sight alone of the senses, when it perceives the sense-object that moves it, uses air as a medium not as a kind of walking-stick, but as a homogeneous part that forms one body with itself, and if sight alone has been given this exceptional ability, along with the ability to see by reflection, one may reasonably assert that it needed luminous pneuma flowing in from above which might encounter the surrounding air and strike it, as it were, and assimilate it to itself." Ḥunayn's version here may be conceived as sometimes loose, sometimes strict translation, and not simply paraphrase.

[151] The walking-stick analogy, rejected by Galen (see above, nn. 143, 145), was used by Chrysippus and rejected also by Alexander of Aphrodisias in his *De anima*; see J. Zahlfleisch, "Die Polemik Alexanders von Aphrodisias gegen die verschiedenen Theorien des Sehens," *Archiv für Geschichte der Philosophie*, 8 (1895): 380-382.

Further pursuit of Ḥunayn's meaning by the phrase "as it were with the shock of a collision," takes us into a brief consideration of the Stoic theory of pneumatic *tonos*. Neither Ḥunayn nor Galen made such a notion into a basic physiological doctrine. In fact, neither writer discusses such a doctrine in a way that allows us to consider it fully proper to his thought. The closest Galen comes to such a discussion appears in *De motu musculorum*, 8,[153] where the tonic activity of a tensed muscle is described as being *like* a rapid up and down motion, the "upward force of the power from the brain" against the inherent downward force of weight, so that "it [an extended limb] *seems* (my emphasis) to remain in the same place."[154] Galen's notion of *tonos* is not truly Stoic, for Galen seeks to find a clear mechanical image when he uses the word. And when Galen develops his doctrine of pneuma, that subtle substance never becomes for him an entity like the Stoic pneuma.[155] Galen's (and Ḥunayn's) refined visual pneuma is simply a material substance without inclusion of Stoic *tonos*, although Galen's psychic pneuma does compare in its elemental makeup to the more active kind of Stoic pneuma, which is dry and warm, drawing its qualities from fire alone according to the Stoic Chrysippus.[156]

In the Stoic doctrine *tonos*, a property of all pneuma, is used to account for the cohesion and unity of an object. Lutz Bloos described *tonos* as follows.

> Because the tonos is conceived as *kinesis* and is always combined with the pneuma, I speak . . . of a movement of the pneuma. This movement of the pneuma which holds together the distinct objects in which it exists, passes out from the middle of the object and returns again to its point of departure so that a closed circle of movement is present.[157]

While *tonos*, as movement of the pneuma, is its tension, this tension is not the same as that of a bow, whose tension can be used up during a motion but is never movement itself.[158] The very being of a thing, according to Stoic doctrine, depends upon pneuma, the motion of which is *tonos*.[159] Simple motion, however, is not intended, for,

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[152] Although Ḥunayn does not support a thoroughly mechanistic conception of vision, he seems to adopt Galen's appreciation for mechanical (not mechanistic) images of the perceptual process. Thus Ḥunayn's retention of a sensate visual pneuma cannot be considered as an appeal to a fully organic metaphor of the sort found in Job of Edessa, *Book of Treasures*, transl. A. Mingana (Cambridge: Heffer, 1935), p. 134, where the sense of vision is said to "draw" images from the viewed object back to the eye by means of an illuminated visual pneuma. Job of Edessa (d. ca. A.D. 835) composed this treatise ca. A.D. 817; it was, with Galen's work, influential on physiological optics in Islam.

[153] Kühn, 4: 403; transl. Goss, p. 10.

[154] Ibid. See David Hahm's understanding of this idea in *Origins*, p. 183, n. 77.

[155] The most useful discussions of Stoic pneumatic doctrine seem to me to be those of Hahm, *Origins*, ch. 5, and of Bloos, *Probleme*, pp., 52–73.

[156] Bloos, *Probleme*, pp. 60, n. 2; 61.

[157] Ibid., p. 65.

> the movement is called tonic motion or a *tonos*, two names connoting tension. This points to an entirely different image, namely, the image of air pressed into an confined space, such as a skin. The image of compressed air gives, on the whole, the most satisfactory explanation of the pneumatic motion and its effects. Such pressure has no local motion and . . . it acts simultaneously in opposite directions. . . .[160]

In the history of Hellenistic physiology the term *tonos* was associated with the term *neura* as long as the latter were considered as sinews, or binders, but when *neura* came to be understood apart from tendons and were seen instead as transmitters of voluntary movement and sensation, the term *tonos* seems to have disappeared.[161] Only a suggestion of that connection remained current by the time of Galen.[162]

For Galen pneumatic *tonos* is not part of the visual pneuma. But this Stoic conception does seem to lie behind Galen's (and Ḥunayn's) explanation of the act of vision through a pneumatic medium. What is the state of the air which has been transformed and completes the passageway from seen object to visual pneuma? The air is clearly *transformed* and has characteristics going beyond those of an Aristotelian medium of sense transmission, for the medium is somehow active and sensate. It is *like* an extension of the optic nerve. It is *like* an extension of the visual pneuma. The creation of this likeness is accomplished *as if* by a blow, "as it were with the shock of a collision." What we have is a strongly implied analogy, which neither Galen nor Ḥunayn wishes to complete, for the completion will *look like* a mechanistic image. The analogy, we suggest, would use a rigid body and would call attention to the sense of vibration at the opposite end when one end is struck sharply. Such a "shock" would best be understood, not in strictly mechanistic terms, but rather in the terms of Stoic pneumatic *tonos*.[163] Because Galen can find no simple and unambiguous materialistic definition for the active state of a pneumatic medium, he simply introduces it and passes on. Ḥunayn follows suit. Yet at this one point, it appears, that Galenic doctrine of vision has good use for a Stoic conception which is otherwise avoided.

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[158] Ibid., pp. 65–66.

[159] Ibid., pp. 66–67.

[160] Hahm, *Origins*, p. 167.

[161] The history of the term *tonos* is reviewed in ibid., pp. 170–172.

[162] Galen's predecessor, Rufus of Ephesus (1st cent. A.D.), said *tonoi* was a name for motor and sensory nerves.

[163] In *De placitis*, VII, 4, De Lacy, p. 448, ll. 19–24, Galen considers as a possible (and not rejected) notion the violent alteration of the nerves by the pneuma, passing only part-way along the nerves and then causing the alteration, which continues on. While this is not the Stoic conception, there are some affinities, primarily the idea of the alteration as a violent affair. The same Galenic conception appears in Ḥunayn, pp. 28, 31.

Following his consideration of the means by which the air is transformed into a pneumatic medium, Ḥunayn turns to the specific attributes of the transformed medium. This is the final part of stage two in his argument. The rationale for specificity of the senses is ultimately the explanation for *how* each sense perceives as well. Attributes of each sense are attributes of the relevant cosmic element, and the way in which each element's qualities characteristically act is the way sensation by means of these elemental qualities occurs. Ḥunayn says,

> This being so, it is best to say that the sense of vision is fiery and luminous, the sense of hearing air-like, the sense of taste water-like, the sense of touch earth-like, and the sense of smell vapour-like. As there are four elements, a sense was created for each one of them by which each is recognised, *i.e.* the phenomena arising in them which are perceptible to the senses. And next to perception is that emanation which arises from vapour, and this is perceived in an unusual manner, as vapour is something half-way between air and water; so they become five [senses] without the existence of five elements.[164]

The nature of vision as revealed by this paragraph of Ḥunayn takes us into an elliptical discourse on cosmology. He does not find it necessary to describe at length a philosophy of the four elements, their qualities, and their interrelationships in a harmonious cosmos.[165] In fact, he could assume that his readers would have in mind at least the elements of the classical Greek world's conception of matter as fire, air, water, and earth along with their respective qualities. He builds on such an assumption. Ḥunayn's intention seems to be the establishment of linkages in a world of discontinuity. The distinctiveness of the senses is obvious enough. The concern of the author is to show harmonious interrelationships among them.

By initiating the paragraph with the phrase, "This being so," Ḥunayn informs us that he is about to explain what follows from the transformation of air into something similar to the visual pneuma. The explanation tells us not only what follows but also what the transformation means, which thereby implies how it comes about. Each of the four mundane elements is assigned a sense. Each of these four senses—we leave out the fifth for a moment—is "like" the assigned element, was created *for* that element (teleological associations intended), and recognizes perceptibles of and in the element.[166] The sense of vision is not fire, but fire-like. Through the attributes of fire we see.

That a sense organ can be based on elemental attributes and not a single element appears in the case of smell, which is vapor-like. For Ḥunayn vapor is here described as "halfway" between the elements air and water, is not an element itself, yet has a separate means of sensation because of the distinctive "emanation" that arises from objects smelled. Galen argues in his treatise on the sense of smell that neither air nor water alone as a medium can successfully account for odors; the dryness of air and the density of water both fail to carry scents.[167] Ḥunayn tacitly accepts the argument and notes a special attribute, the "emanation," of vapor which makes it more than just a mixture of air and water.[168] On the other hand the elemental qualities pertaining to the moisture of vapor, wet *and* dry, make the sense of smell as basic as the other senses. Each accounts for human perception of a basic part of the order of things.

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[164] Ḥunayn, p. 37. This is a modification and compression of Galen, *De placitis*, VII, 5-6, De Lacy, p. 462, ll. 1-17.

[165] For all its extravagances, the book by Leo Spitzer, *Classical and Christian Ideas of World Harmony. Prolegomena to an Interpretation of the Word "Stimmung,"* ed. Anna G. Hatcher (Baltimore: Johns Hopkins Press, 1963), offers a fascinating and insightful discussion of various forms of world harmony. See e.g. pp. 7-8 on the ancient Greek conception and its strengths, which were *not* scientific in the modern sense. See also Rudolf Allers, art. cit. above, n. 67.

[166] Likewise Galen, *De placitis*, VII, 5, De Lacy, p. 462, ll. 3-4: "they required the alterations caused by similars." Again, at *De placitis*, VII, 6, De Lacy, p. 468, ll. 15-16, he says, "Perception, then, is not alteration, as some say, but discernment of alteration."

After placing each of the senses in its cosmological framework, Ḥunayn returns to vision, which, in its luminosity, is created essentially to know color. He concludes,

> The sense of vision having been created to the end that colours shall be recognized by it, it must necessarily be luminous, as only luminous bodies, and no others, have the peculiarity that they are transformed by colours. A clear proof of this is [furnished by] the air surrounding our bodies: it is when it is in the highest degree bright and pure that its transformation by colours is most marked. In the same connection we sometimes find the following: if a man is lying under a tree and the air is in this condition, the colour of his clothes takes on the colour of that tree, because the air has become inbued with that colour. Moreover, we often see that the air takes on the colour of the wall, if the air meets it when it is luminous, and it [the air] transmits the colour equally to another body, especially when the colour is one of the conspicuous ones such as white and red and other colours of intense brightness.[169]
>
> In the same way in which the air is entirely transformed by the sunlight until it becomes luminous and its light similar to that of the sun—and this happens only when it is met and struck by the sunlight—it is also instantaneously transformed by the colours,[170] and in the same way that it is transformed by the colours, it is also transformed, with the utmost rapidity, by the luminous pneuma running from the brain to the eyes, when it meets and encounters it on its way from the pupil.

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[167] Galen, *De instrumento odoratus,* 2, says, "For whatever streams off the surface of a body is the substance of odorous matter. One recognizes this quite definitely with roses and things similarly simple, which swiftly become smaller and drier than they were, showing unambiguously that the moister parts have escaped from their substance." ed. Kühn, II, p. 862; ed. Kollesch, p. 40.

[168] See above, n. 53, for the complex background of the Galenic doctrine of vapor and smell. Ḥunayn follows a different Galenic source here than used earlier in *Ten Treatises* to define vapor. Ḥunayn's notion of the "emanation" of vapor presumably derives from Galen's mention of the emission of odorous vapors as well as their volatile nature. See above, n. 167.

[169] This paragraph is a paraphrase of Galen, *De placitis,* VII, 7, De Lacy, p. 470, ll. 3-11.

[170] Thus far in this paragraph Ḥunayn paraphrases Galen, ibid., p. 470, ll. 11-13; but from that point Galen launches into an extended debate against parts of the Aristotelian theory of vision, dismisses Epicurean and Stoic notions along the way, and generally dissipates anything we would call a unified argument (ibid., pp. 470, l. 13-474, l. 29). As a result Ḥunayn does not attempt to use this argumentative material in any consistent way, although a few extracts from it appear in *Ten Treatises.*

> Thus the air is considerably and necessarily altered by the influence of these three things: the sunlight, the bright and shining colours of celestial objects[171] and the visual pneuma which strikes it on leaving the pupils.[172]

Some very simple and very important points are made in this discussion of color. Ḥunayn integrates color with luminosity in vision—only color and nothing else. Of the discernment of size, shape, and so on, by the eye we find nothing here. As luminous sensation, sight, by definition, recognizes colors. The detailed description of examples in which some objects take on colors from other objects becomes significant as a series of examples wherein the luminous air is always responsible for the transfer of colors. The concluding statement (second paragraph) offers more insight yet. We learn that the air is "met and struck" by the sunlight in order to become luminous. The words "met and struck" suggest that the image for transformation of air by sunlight is meant to be the same as the image for transformation of air by visual pneuma.[173] The words also reinforce the impression that there is a total qualitative continuum from viewed object to the brain. Transformation of the medium by colors is like the transformations by sunlight and visual pneuma in being instantaneous. Color, then, becomes an attribute, a luminous quality, of the air medium. As long as the air medium is a transformed, pneumatic medium there is a qualitative continuum from object to brain and therefore immediate perception of a quality such as color by the brain. Ḥunayn emphasizes the equivalence of sunlight, color, and pneuma as essential influences on the medium. They work similarly, being luminous, and they work together, thereby creating the essence of vision.

The third and final stage, as we have called it, of Ḥunayn's argument for the pneumatic medium theory of vision is a quick summation, as interesting for what it does not say as for what it does say.

> It is evident from what we have said, that our vision of things is effected solely by means of the air between us and them; we have found this to be clearly perceptible, so that all people agree upon it.[174] When the air is luminous, either by reason of [the action of] the sunlight or [that of] another lucid body, it becomes to the visual pneuma as it were an organ and a similar adapted instrument and to the vision an instrument replacing the nerve by which this pneuma is sent down from the brain to the eyes. And as the perception of things which are perceived by the eye reaches the brain only through the optic nerve between it and the eye, so the visual pneuma perceives the objects of vision by means of the air, only if it is luminous in the space between them. At the same time that it perceives the objects of vision it also

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[171] Meyerhof (Ḥunayn, p. 38) interprets this phrase to mean the planets, but a better suggestion seems to be the phenomena of rainbow, halo, etc., mentioned by Galen, *De placitis,* VII, 7, De Lacy, p. 472, ll. 6–7, since these phenomena are more essentially relevant to color.

[172] Ḥunayn, pp. 37–38.

[173] See above at n. 150 and subsequent discussion.

[174] Surely Ḥunayn believes he has proven this point for his readers. However, we may also look at the statement as a kind of summary of Galen's harangue against the supposedly erroneous parts of Aristotelian theories of vision, in *De placitis,* VII, 7, De Lacy 470, 18–472, 16; furthermore, Galen, ibid., 472, 25–26, makes the same summary statement.

perceives the connected circumstances, such as the size of those bodies and their other conditions, as has been mentioned before.[175]

First let us recall that this is a conclusion to a proof of the pneumatic medium theory as the only satisfactory theory for explaining the perception by sight of those properties of things which we do, in fact, see. By means of a pneumatic medium we perceive "the objects of vision" (the luminous properties) and the "connected circumstances" (e.g. size, and other properties which are not luminous but are perceived by means of the luminous medium plus reasoning). Neither the intromission nor the extramission theory is able to account reasonably (viz. economically, according to Nature) for our vision of distant objects. Ḥunayn's final review of the passage of vision by means of the pneumatic medium from object to the eye and from there to the brain by means of visual pneuma may seem to be incomplete in one way. We are not told in detail how the perception travels from eye to brain. There are various options, as pointed out by David Lindberg, and any one of them seems to require a great deal of interpolation into the text. The options seem to be (1) optical radiation, a continuation of the process through the air to the lens, (2) some kind of neurophysiological transmission, beginning at the lens, (3) a simultaneously optical and neurophysiological passage.[176] As conceived, each of these options depends upon an understanding of vision in terms of functional physiology. For this reason, none of them is acceptable for explaining the exact means of visual transmission from lens to brain. In fact, as will be seen in the discussion below, the transmission from eye to brain has already been fully explained but in a way that a modern reader, thinking in functional terms, is unlikely to have noticed.

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[175] Ḥunayn, pp. 38-39. Galen, *De placitis*, VII, 7, De Lacy, pp. 472, l. 25-474, l. 7; 474, ll. 10-12; 474, ll. 20-22; makes the same points appearing in Ḥunayn's summation, though in very different wording and interspersed with controversy. Where Galen ends, Ḥunayn also stops, although with a much more ordered and conclusive note. Galen does not return again in this book to the subject of vision.

[176] Lindberg, *Theories*, pp. 40-41, presents the optical and neurophysiological alternatives, and he argues persuasively for a neurophysiological interpretation; on p. 232, n. 55, he reviews arguments for the optical interpretation and mentions Rudolf Siegel's extravagant hypothesis (my characterization) of a simultaneously optical and physiological passage from lens to brain. See Siegel, "Principles and Contradictions" (above, n. 77), pp. 265-269; as Lindberg notes, "Unfortunately, Siegel presents no textual evidence to support his position;" Lindberg, *Theories*, p. 232, n. 55.

V. THE CRYSTALLINE LENS

In tracts 1-3 of the *Ten Treatises* Ḥunayn dealt successively with (1) "the nature of the eye and its structure," (2) "the nature of the brain and its use," (3) "the optic nerve, the visual pneuma and the vision."[177] The first two focused attention upon the *natures* of the parts concerned and how these were in accord with the order of Nature. The third did not depart from a consideration of natures and Nature, but rather made full use of the previously established knowledge to explain vision as a process of transmission. In order to bring together the essence of Ḥunayn's understanding, let us turn to a question which Ḥunayn found easier to answer than have modern scholars. Once we see clearly what occurs at the crystalline lens we shall be able to see the amazingly simple unity of Ḥunayn's theory of vision.[178]

What does the lens do? Immediately we shall label this question illegitimate and misleading, for it suggests that there is some kind of *distinctive* and *unique* activity or occurrence at the lens. Such is not the case, and we shall fare better with a revised initial question: What is the nature of the lens? The lens is "white, transparent, luminous," and the purpose of these qualities is to make the lens, like the visual pneuma and the pneumatic medium, able "to receive the changing of colours rapidly."[179] Because of these qualities, "vision is *in* (my emphasis) this humour [the lens], and not in any other part of the eye;"[180] no other part of the eye is luminous; with regard to the parts of the eye identified in tract 1, we can find vision only in the lens. But vision is *in* the lens inclusively, not exclusively. Just as the pneumatic medium beyond the eye and the visual pneuma between brain and pupil, the lens is a luminous medium of transmission and the only part of the eye proper about which we can speak this way. Light simply *passes through* the cornea, which is called thin and white.[181] Again, the luminous pneuma *passes through* the aqueous humor.[182] Of the retina and lens we must remember that they form together a unit with the optic nerve, making an extension of the brain for the passage of visual pneuma, which fills this container, as it were, and can pass farther only through the lens, because of its transparency and luminosity.[183] Of the vitreous humor we hear nothing about any obstructive characteristics, only that it is nutritive and passes nutriment from the blood vessels in the retina to the lens. The vitreous in nature is "glass-like . . . and nearer to the white colour and transparency [of the lens] than the blood."[184] Like the aqueous humor, the vitreous is close enough to the lens in properties to cause no difficulty for the flow of pneuma but quite unlike the lens in its quality of luminosity. While the lens *does* nothing, it *is* of such nature that it is the only part of the eye wherein we can find the power of vision residing.

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[177] Taken from his table of contents for the book: Ḥunayn, p. 1.

[178] The following account is more than section II of this paper could bear, because modern preconceptions require the full elaboration of sections III-IV as a grounding for reassessment of the lens and its description in section II, which the reader may now wish to review.

[179] Ḥunayn, p. 3.

[180] Ibid., p. 4.

[181] Ibid., p. 9.

[182] Ibid., p. 10.

What do we mean when we say power of vision, sense of vision, and instrument of vision, all of which can be found in the lens? Concerning the visual pneuma Ḥunayn, we remember, says such things as: "the pneuma . . . by means of which the vision is achieved";[185] "the luminous pneuma, which effects vision";[186] that "by which vision is achieved";[187] "pneuma through which vision is effected";[188] it is a "medium" for perception.[189] Clearly he conceives the visual pneuma to be percipient and essential in sight. In fact, the power of vision and the sense of vision are at least as appropriately lodged in the visual pneuma as in the lens. If we turn to the phrase "instrument of vision" (*ālat al-baṣar*), we find it used to describe the lens,[190] and also to describe the complete continuum from brain to object.[191] The word "instrument" (*āla*) appears as a term for the pneumatic medium, considered as an instrument of the visual pneuma.[192] Nowhere in tract 1 is the lens called the "instrument of vision." For the moment we may conclude that the notion of an "instrument" for Ḥunayn is not specific enough to mean a part distinctively and uniquely charged with carrying out a certain function. As the "instrument of vision" the lens is simply a part with a specific nature.

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[183] See above, n. 22. Note also that Galen, *Usefulness*, X, 1-2, transl. May, p. 465, describes the retina as an extension of the brain, not to be called a separate tunic. At the same place Galen says, "Its [the retina's] principal and greatest usefulness, that for the sake of which it was brought down from above, is to perceive the alterations of the crystalline humor and in addition to convey and transmit nutriment to the vitreous humor." Concerning the perceptiveness of the retina, we can say that Galen is speaking loosely, for it is the contained visual pneuma that makes the retina in any sense perceptive. Concerning the "alterations of the crystalline humor" we need only recall that the pneumatic medium and the visual pneuma likewise carry alteration, for both Galen and Ḥunayn.

[184] Ḥunayn, p. 6.

[185] Ibid., p. 7.

[186] Ibid., p. 8.

[187] Ibid., p. 17.

[188] Ibid., p. 20.

[189] Ibid., p. 28.

[190] Ibid., p. 47 (Arabic p. 120, line 3). Meyerhof translates *āla* as "organ." I follow Emilie Savage-Smith's suggestion of "instrument" instead, for she remarks that Ḥunayn's translation of Galen's *De usu partium* uses *āla* for the systems of nerves, veins, and arteries, while using the vague word *'uḍw* to translate "part" (*morion*) and to include the notion of "organ" with its physiological connotations.

[191] Ḥunayn, pp. 20, 125 (Arabic pp. 89, line 31; 193, line 3). Note that in the latter of these two locations the phrase *ālat al-baṣar* is used only to describe the subject of tract 3, not to indicate the subject of tract 1, where the lens is central.

[192] Ibid., p. 38 (Arabic, p. 111, l. 13).

Adding a bit of potential difficulty to our understanding is the tripartite division of tract 5,[193] on the causes of the disturbances of the eye, in which the lens is called the "instrument of vision"; the "faculty of vision" is distinguished from it, with disturbances of this faculty caused by diseases of the brain or of the optic nerve; finally there are lesions of those things "which serve the vision," and among these are included the other parts of the eye, especially those in front of the lens. Among these forward parts of the eye serving vision is found the visual pneuma, which is said to be subject to lesions of its quantity and its viscosity.[194] From all this we can conclude that Ḥunayn's vocabulary in the matter we are addressing is not consistent enough to draw conclusions, unless we find that the terms used and the explanations of the relevant entities are mutually specific. Surely the visual pneuma is not just one of the anterior parts of the eye and only of service of vision; yet it is so discussed in tract 5. On the other hand, the lens as "instrument of vision" needs to mean no more than that the lens is the one fixed "instrument" in the eye where vision can be localized, since the lens is the luminous part of the eye. To demand a modern functional specificity from Ḥunayn's labels in tract 5 seems both impossible and a mistaken enterprise.

Ḥunayn's discussion of cataract sheds light on the question of the lens. In his anatomical section he says, "the vision ceases when cataract intervenes between it [the lens] and the perceptible object, and . . . the vision returns when the cataract is removed."[195] Here the problem is one of intervention in the visual pathway. When discussing cataract in connection with the visual pneuma there is no mention of the lens. Instead the concern is with the presence or absence of pupil dilation in one eye when the other eye is closed. If dilation occurs, "the power of vision has been left normal."[196] Tract 5 also describes cataract and its causes. In general, tract 5 shows that stoppage of sight results either from changes in qualities so that luminous passage is impossible or from obstacles to a rectilinear path of vision from the lens forward. Cataract is definitely one of the latter kind of obstacles, and it is also a qualitative change in the consistency of the aqueous humor, according to Ḥunayn.

> If its [the humor's] thickness is excessive and extends throughout the whole of it, it prevents vision, and this disease is called cataract. If it is in part of it, it may be in connected or in separate parts. If in connected parts it may be at the centre or in the periphery. If it is in the center, the afflicted subject sees a hole in every object, as he thinks that all that he cannot see of an object is deeply recessed. If it is in the periphery, it prevents the eye from seeing many objects at the same time, so that he is obliged to look at every one of the objects individually on account of the small size of the optic tube [viz. the optic cone][197]

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[193] Ibid., pp. 47–53.

[194] Ibid., p. 51.

[195] Ibid., p. 4.

[196] Ibid., p. 30; similar concern with pupil dilation in cataract is expressed later, at p. 70.

[197] Ibid., p. 50.

In the case of total cataract the aqueous humor's qualities are sufficiently changed so that visual pneuma can no longer pass beyond the lens to the pupil. In cases of partial cataract different sorts of apparent obstacles appear, but some vision is still possible. That is, visual pneuma can pass beyond the lens and forms what part it can of an expanding optic cone through the humor and the pupil to the outside medium. We have no reason to think here of the lens as anything more than we have already described.

One final possibility for locating a distinctive function of vision in the lens is making it the place where rectilinear rays are received and then passed on to the brain in some non-geometrical fashion.[198] Here we must consider the nature of the optical-geometrical arguments of Ḥunayn as well as their relevance to the peculiar status of the lens in the eye. We have already recognized that Ḥunayn's use of geometrical arguments appearing in Galen may lead to different meanings.[199] Ḥunayn seems also quite capable of omitting parts of Galen's geometrical arguments and thereby creating detailed differences of doctrine, which fit his different purpose for writing. Especially relevant is the argument in tract 3 concerning the passage of visual rays from the chiasma,[200] where he says,

> . . . since each perceived object is seen only by the glances proceeding from the two pupils; and since these looks are like rectilineal lines going straight forward,[201] in the manner in which the rays of the sun penetrate through a window into a house; and since the origin of those lines is united and compressed, whilst their end is broad and separated; and since their general shape in each eye is conical, *i.e.* the shape of the big pine-cones, it is an unavoidable necessity that the two central lines of these two [conical] shapes known as axes should be in the same position and that their course should run on the same plane, until the perceived object reaches him [the observer] at the same spot in his eye; (if this were not so, the two lines would not both reach him at the same spot in his eye.)[202] In the same way it is equally necessary for the lines around each of the two axes to be in a position which is alike in both eyes; [finally] the position of the entire conus formed by the lines coming out of one of the eyes must be similar to the position of the entire conus formed by the lines coming out of the other eye. The inevitable consequence of this state of affairs is that the origin of the glances proceeding from the two pupils is the same, and that their course lies along the same flat plane. This beginning and origin from which the going forth of those looks proceeds is that place of junction of the two canals which run through the two optic nerves at the place where they become one; if the glances proceed from this simple origin and then come out into the pupils and regard the perceived object, they reach it in its place and see it as one. . . . the following three things must be situated in each eye in

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[198] Lindberg, *Theories*, pp. 40–41, argues for this.

[199] See, for example, above at n. 13 and subsequently on their respective arguments concerning the shape of the lens. Generally, Galen's arguments were more geometrical in nature; he seems to have cherished the use of geometrical arguments in advancing philosophical status for physiological doctrines.

[200] See above, sect. IV, A.

[201] Galen speaks of a "visual ray" extending from the pupil to the object seen and also exemplifies the lines called "visual rays" by the filaments of a cobweb in *Usefulness*, X, 12, transl. May, pp. 492–493.

[202] Meyerhof notes (Ḥunayn, p. 25) that this parenthetical clause appears in only the older of the two MSS. (Cairo MS.)

> one straight line and must follow the same direct course, viz. (*a*) the pupil, (*b*) the origin of the whole eye there where the optic nerve begins to appear and to be visible, and (*c*) the place of junction of both nerves from which they begin their course [to the eyes] all lie on the same plane.[203]

As we have already seen, the essential concern of this passage is to show that the optic chiasma, the juncture of the two optic nerves, functions primarily to prevent double vision. However, when we examine the text for more information about the means of passage of these rays and their focal and intersection points, we discover much of significance. First, it is notable that Galen describes the lines as rectilinear all the way from the viewed objects to the brain,[204] while Ḥunayn says nothing here or elsewhere about straight lines beyond the chiasma and towards the brain. At the very least we can conclude that such a point is unimportant to Ḥunayn. Initially in this argument he says that the "glances," which are rectilinear and conical, proceed "from the two pupils," but this is not enough to tell us that the optical cone begins at the pupil. Immediately thereafter he describes "the origin" of the rays forming the cone as "united and compressed," yet he does not locate the origin of the cone at any point or organ. Further on he identifies the "origin" of the "glances proceeding from the two pupils" as the chiasma, but this does not seem to mean that the visual cone originates at the chiasma, for his concern is with the "position" of each optical cone relative to the other, and the relative positions, or orientations, are determined by the axial rays. In speaking of the chiasma Ḥunayn refers only to the axial rays, as we see at the end of the paragraph when he situates three things in a straight line: (1) the pupil, (2) the opening of the optic nerve into the eye, (3) the chiasma. Following Galen in this three-point lineup,[205] Ḥunayn does not locate the origin point of the visual cone, and he makes no mention of the lens at all. It might be claimed that Ḥunayn's account is incomplete and that we may find more of his (implicit) doctrine in Galen, but to do so will require more than an occasional word or phrase. If, for example, we ask what new fact is indicated by Galen's mention that the retina (as part of the extension from brain to lens) is "to perceive alterations of the crystalline humor,"[206] a phrase not to be found in Ḥunayn, we need only follow the line of interpretation already laid out above, viz. that the "alterations" of the lens are in no way distinguished from the alterations described by Ḥunayn for the pneumatic continuum from object to brain. The lens is the one part of the eye which is luminous and by its nature thereby a link in the continuum. The same conclusion emerges from a reconsideration of the passages on cataract.[207]

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[203] Ḥunayn, pp. 25–26.

[204] Galen, *Usefulness*, X, 13, transl. May, pp. 498–499.

[205] Ibid.

[206] *Usefulness*, X, 1–2, transl. May, p. 465; quoted by Lindberg, *Theories*, p. 41, in pursuit of his argument for a second, postcrystalline (neurophysiological) phase of transmission. At p. 231, n. 49, Lindberg says, "Ḥunain confirms the existence of this second [post-crystalline] phase of transmission when he writes that perception is transmitted 'by the nerves, until it reaches the brain and is perceived by the allotted part of the soul, and the individual is informed [of the sensation]'." Surely there is transmission all the way to the brain in all the senses, but that transmission is uniform for each sense; distinct and dissimilar phases in the transmission are not mentioned. Ḥunayn's discussion at this point deals with all the senses together, makes no special reference to vision as such, and does not use the term for "instrument." (*āla*) found in conjunction with the lens in tract 5 (above, n. 190); see Ḥunayn, pp. 28–29 (Arabic text pp. 99, ll. 15–100, l. 1).

The place of geometry in Ḥunayn's visual theory is carefully circumscribed. He applies it, modifying Galen, to show the purposeful structure of Nature. In the description of the optical cone, geometry shows us the shape of the visual rays proceeding from the eye outward, but geometry is not used anywhere to characterize the nature of the visual rays. We understand that vision is accomplished through a pneumatic medium shaped like a cone, but the nature of visual fire (light) and visual pneuma is never specified as essentially geometrical or rectilinear. Instead, light and visual pneuma simply follow such a path and create a conical pneumatic continuum. An intriguing corollary is the secondary, or indirect, perception by sight of the attributes of objects defined spatially, or geometrically, such as size, distance, location. When dealing with the essential quality of luminous perception, Ḥunayn speaks only of color, and the other, geometrical attributes are determined indirectly, or partly by reason.[208] Vision therefore follows geometrical lines but is not in its essence a geometrical entity. The geometry is one of Nature, providing the most economical and effective pathway, not a geometry within the very nature of luminous entities.

Whether we look at the geometry of vision, the discussions about cataract, or the exact terminology used, we find no special function for the lens. We do, however, find a nature of the lens. It is not only transparent, as are the healthy humors before and after it, but also luminous. Additionally, it has one special character in that it is fixed. It is fixed as terminus of the unit formed by the brain-optic-nerve-retina-lens and thereby becomes the one element in that container to be fully like the visual pneuma in its elemental luminous quality. If we look for additional reason for making the lens specifically luminous, we are asking a question inappropriate to Ḥunayn's teleological and cosmologically grounded conceptions. At best we can say that the lens, as the end point of the unit from the brain, *should* be luminous because of its nature and location.[209]

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[207] See above at nn. 195–197.

[208] See above at nn. 144, 164, 172.

[209] Another way to say this is to say that the lens is the only *localized* part of the visual continuum that is sensitive, but the character of its sensitivity does not differ from the rest of the pneumatic continuum. That Ḥunayn probably understood Galen to mean the same thing is suggested by Ḥunayn's translation of *De usu partium*, X, 2, where he shows Galen saying, "At the location where this tunic [the retina] is inserted, the departure of the branch of nerves stops and ceases and extends no farther. The reason is that it had then completed the purpose for which it was intended and was connected with the crystalline [humor] and was able to be a messenger communicating eloquently (*rasūl balīgh li-l-dimāgh*) with the brain, informing it (*yunabbīhu*) of what sufferings (*al-ālām*) occur in the crystalline [humor]." The text is found in Madrid Escorial MS. arabica 850, f. 122, and in Paris BN MS. arabe 2853, ff. 161v–162r; I owe the citations and the translation to Emilie Savage-Smith. Cf. Margaret May's translation (*Usefulness*, p. 467) from the Greek: "Where it is first inserted, the outgrowth from above checks its advance and comes to a halt; for the purpose for which it was sent down has now been accomplished, and it is inserted into the crystalline body [the lens], the changes (*ton pathematon*) in which it can faithfully report to the encephalon."

VI. PROBLEM-SOLVING AND COSMOLOGY

Having completed our detailed analysis and interpretation of the visual theory in Ḥunayn's *Ten Treatises,* let us turn briefly to the issues of problem-solving and cosmology. Our interpretation has viewed the visual theory as an essay on the reflections in the microcosm (in fact, in one part of the microcosm) of the basic elements and elemental qualities in the macrocosm. This kind of micro-cosmology is neither abstruse nor rare in the Middle Ages. It does not presume as much as more highly structured microcosmic outlooks. However, it does presume that the qualities of the four elements are basic determinants of the natures of things, and it does give real significance, not just lip-service, to those natures in any study of the observable world. As we have seen, Ḥunayn used teleology to give meaning to structure in anatomy, and this can hardly be called unusual; it appears as a very pronounced trait in Platonist and Galenist writings. The sense of order Ḥunayn found in his study of the eye was not simply taken from Galen but was very much his own. It was partly an order of argument (scholasticism, if you like) and partly a perceived order of Nature. In building his sense of order Ḥunayn preserved doctrinal essentials of Galen but omitted, compressed, and changed various details and intentions of Galen's arguments. When we combine Ḥunayn's sense of order with his use of elemental microcosmism we have the guiding principles for his visual theory.

For an alternative point of view we should look at David Lindberg's *Theories of Vision,* which appears to contain the only consistent and well-stated interpretation previously available. In a careful analysis of Ḥunayn's visual theory,[210] Lindberg proceeds to identify important questions raised within the tradition of "Galenism."[211] As he points out initially, "The importance of these two books [by Ḥunayn] is not that they contain anatomical or physiological novelties or new departures in visual theory, but that they represent the penetration of Galenic theories into Islam."[212] In embarking on exposition, Lindberg outlines and discusses the theory in terms of the salient questions and contributions in the history of Galen's theory of vision. Implicit questions, or problems to be solved, which determine the content of the exposition are, at the general level, such as: (1) What are the functioning parts of the eye? (2) How does each part contribute to the passage of visual pneuma? (3) By what steps do visual pneuma and the other media (or active participants) bring about vision? Within these general questions there emerge specific problems of anatomy and physiology. The problems preliminary to an elaboration of a visual theory (as treated by Lindberg) are these: (1) the position and importance of the lens, (2) the positions and functions of each of the other parts of the eye, including an adjudication of differing opinions about the number of tunics in the eye, (3) the origin, path, and structure of the optic nerves, (4) the functions of the juncture (chiasma) of the optic nerves in their course from the brain to the eyes.[213] Lindberg's approach to each of these issues is restricted to the points which will *directly* and *functionally* (in a modern sense) undergird the discussion of visual theory. The problems discussed by Lindberg under the heading of vision itself are: (1) an assessment of the alternatives offered by the ancients, (2) the interaction between visual pneuma and the external medium of air, (3) the means by which the visual power perceives the qualities of an object, (4) the process whereby sensation returns to the brain in order to complete perception.[214] It appears that Ḥunayn's understanding differs from the modern historian's. The nature of the difference should be underscored, for it is more a matter of framework than of particulars. As a rule Lindberg says nothing that is not said by Ḥunayn,[215] and the order of presentation of topics is generally the same in both. Where then is the difference? First, Lindberg says much less than Ḥunayn, and this is not simply a matter of omission through summary. Second, the additional information given by Ḥunayn allows us to see a different relationship of parts than the *implicit* relationship emerging from Lindberg's problem-oriented analysis. Finally, Lindberg does not *deny* the relationship we claim to find through textual exposition. He simply ignores it, presumably because it seems external to the essential problems dealt with in the text.

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[210] Lindberg, *Theories,* pp. 32-42.

[211] By "Galenism," Lindberg appears to mean a systematic theory of vision developed by Galen. While I think it unfair to place excessive weight on Lindberg's use of the term, I do find it misleading to conceive of a tradition *within* the development of visual theories that might be labeled "Galenism," as if the medieval theorist were thinking only of Galen's visual theory and were ignoring the remainder of his thought. Owsei Temkin, *Galenism. Rise and Decline of a Medical Philosophy* (Ithaca: Cornell U. P., 1973), p. 93, observes, " 'Galenism' . . . was a medical philosophy, a set of more or less cogently connected principles, doctrines, and concepts, ascribed to Galen, used in thinking about man's body in health and disease and shaping the physician's attitude to his profession and to human life." In addition, Temkin notes, Galen was much better known as a physician *and* philosopher in the East than in the Latin West. On Galen and towards a fuller definition of 'Galenism' for the future the most important recent work is probably Luis García Ballester's *Galeno en la sociedad y en la ciencia de su tiempo* (Madrid, 1972); a useful, initial assessment of this book is by Carl J. Post and John Scarborough, "On Ballester's Galen: An Extended Review," *Episteme,* 9 (1975): 3-31. The works of Rudolf Siegel, despite some merits, are distinctly counter-productive to any attempt to define 'Galenism'.

The relationship of parts as seen by Lindberg is sequential. Each question answered completes a block in a mosaic. The full mosaic provides a description of what happens in the process of vision. Insofar as the descriptive analysis does not go beyond the *explicit* meaning of the text, no fault need be committed in completing the mosaic. Where the description requires more extensive interpretation in order to get at the *implicit* meaning of the text, as in the case of post-crystalline transmission of sensations returning to the brain, the problem-solving approach supported by Lindberg offers less guidance in finding the implicit meaning. However, an apparent virtue of the problem-solving outlook is its clear identification of schools of thought. Lindberg's book identifies and nicely characterizes a medical tradition (as well as others) in terms of the questions about vision which consistently appear in medical writings. Furthermore, a persuasive distinction between the medical, the "philosophical," and the mathematical traditions in optics can be made by reflecting upon the different sets of questions asked. Lindberg observes.

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[212] Lindberg, *Theories*, p. 34. Ḥunayn's second work referred to is *Book of the Questions on the Eye*. This handbook contains no new information beyond the *Ten Treatises*.

[213] These issues are discussed by Lindberg, pp. 34–37.

[214] Ibid., pp. 37–41.

[215] Where Lindberg and I differ, I have recorded his views and my reasons for differing.

> [Despite some overlapping] this threefold classification defines the principal battle lines among medieval theories of vision. I would not minimize the importance of other issues, such as the intromission-extramission controversy, but the dispute among physicians, natural philosophers, and mathematicians was the more fundamental in that it brought into question the very aims of optical theory.
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> The nonmathematical orientation of the Galenic and Aristotelian theories of vision should be emphasized. In them we find no geometrical analysis of any significance, no science of catoptrics or dioptrics, hardly more than a mention of the rectilinear propagation of light. In place of the geometrical achievements of Euclid and Ptolemy, we find a discussion of ocular anatomy and physiology and an analysis of physically possible modes of radiation. We are here able to perceive the chasm separating various approaches to the problem of sight. The Euclidean theory on the one hand and the Galenic and Aristotelian theories on the other are simply incommensurable, because they have fundamentally different aims.[216]

We can easily discern these aims by looking at the questions asked in each of these traditions. The questions clearly involve different intellectual traditions with their vocabularies and methodologies. The mathematical tradition in optics is Euclidean. The medical tradition is Galenic. The philosophical tradition differs from both of the others. A descriptive analysis of a given writer in any one of these traditions will reveal a more-or-less characteristic set of questions asked and answered. We might call such a description, carefully done (as by Lindberg), a material and methodological infra-structure of a theory. The problem-solving approach to visual theory can show answers to most of our "what?" questions. But the relationship of the parts in Ḥunayn's theory is not the subject of "what?" questions alone. We are looking for more than a sequence of pieces in a mosaic. We wish to find the hierarchy of questions which gives more significant meaning to the description found in Ḥunayn's work than the value accruing from continuation of a professional/methodological set of questions. What makes the mosaic attractive? What principle of organization can be found in the mosaic described?

What should we conclude about the place of problem-solving in Ḥunayn's treatise? He knew and used a large body of literature in medicine in general and on the eye especially. Furthermore, he used specific arguments concerning specific questions. In short, his approach was in many ways restricted to the tradition of the literature as it had already developed. But the restrictions under which he wrote and the information—and traditions—which he used do not tell us, in themselves, how he conceived his subject matter. To use Galen, and even to be a Galenist, may call as much for notable modifications as for unvarying imitations of Galen; there also remains the option of choosing *which* Galen to use. It should be admitted, then, that all the questions, or problems, identified by Lindberg were parts of Ḥunayn's discussion. They were important parts. But the answers were not generally given in efficient-causal, or "functional," terms, and the problems did not shape the discourse;[217] they only filled the framework provided. The framework within which the questions fell was cosmologically determined, and the *meaning* of the answers given was also provided by the micro-cosmology of the treatise. When we ask about the meaning of the doctrines (and problems) in Ḥunayn's work, we ask not only "what?" questions but also "how?" and "why?" questions. We inquire not only what the functioning materials of the sensitive eye are (tunics, humors, a central lens, etc.), but also how these parts work (elemental properties) and why such answers are meaningful and satisfying (microcosmism). Without a micro-cosmology Ḥunayn would have found little sense in the questions and *would not always have arrived at the same answers.* The significance of the lens is our best example of this judgment. While the problem-solving approach allows generally adequate description and a clear designation of methodological traditions, it locks the historical investigator within the description and does not indicate why the problems are significant. It also eliminates from serious consideration such *apparently* extraneous matters as the discussion of senses other than vision. Insofar as Ḥunayn's visual theory is seen through the problem-solving approach, it is seen in part and without framework, in descriptive sequence and without a hierarchical order.[218] His problems find their complete solutions only within a philosophy of Nature, which we have called a micro-cosmology.

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[216] Reprinted from *Theories of Vision* p. 57, by D. C. Lindberg by permission of the University of Chicago Press.

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[217] In fact, it seems that the separate treatment of very specific questions was used by medievals more to attack and call in doubt alternative theories than to advance or expand a favored theory.

[218] From all this, one can at least entertain the hypothesis that *any* visual theory depending on Galenic ideas, and especially on the ideas of visual pneuma and/or pneumatic medium, will depend heavily upon cosmological doctrine. At the risk of belaboring my point with other cases, I call the reader's attention to the brief passage in al-Fārābī's *Ideal State* in which a visual theory is used. In itself the passage seems likely to qualify as an Aristotelian theory of vision, but in its larger, philosophical context the passage shows a major debt to Plato's conception of vision. On al-Fārābī see my note, "Al-Fārābī on Extramission, Intromission and the Use of Platonic Visual Theory," *Isis*, 70 (1979): 423–425.

VII. SUMMARY

To find a micro-cosmology as organizing framework behind the questions asked in Ḥunayn's *Ten Treatises* is not to suggest that Ḥunayn was writing as philosopher rather than as physician. To understand the work fully a reader must understand this cosmological approach, but it is an organizational system put to the service of medical practice. Ḥunayn's own explanation of this goal comes very simply and directly at the beginning of the tenth tract. The *Ten Treatises* as we have it today offers a revised and integrated version of treatises written separately over a period of thirty years or more.[219] These separate works pursued, as he said, distinct goals, but not contradictory goals, and Ḥunayn took the opportunity, when asked, to fit them together in an orderly fashion. We may assume that he did a certain amount of rewriting as well in this process of collection. His product he described as "a book containing all the knowledge necessary for those who wish to treat the diseases occurring in the eye in a reasonable manner."[220] He then gave a short characterization of the contents of each treatise. These characterizations succinctly and explicitly state that medical *practice* is the goal of each tract, and the statement closing the summary of the third tract puts the first three together as a unit which gives "intimate" knowledge of the "instrument of vision" (*ālat al baṣar*).[221] This knowledge, as put together in the *Ten Treatises,* is not medical philosophy but rather philosophical medical practice.

In the course of our analysis we have made continual comparison between Ḥunayn's work and Galen's *De placitis* and *De usu partium.* However one chooses to interpret Galen's purposes in those two works, the apparent purposes of Ḥunayn in *Ten Treatises* is surely different. The systematizing achieved by Ḥunayn came readily enough, given his practical goal. Not only did Ḥunayn shift from the polemical approach of Galen to a more pedagogical approach, but also from a more theoretical approach to a more applied one. If there is theory in Ḥunayn's work it is subordinated to the directive goal of medical practice. This can well explain the more concrete, sometimes elliptical, character of Ḥunayn's adaptations of Galenic optical geometry. Ḥunayn disregarded some of Galen's linear analysis of the internal passage of the visual pneuma. Ḥunayn treated the shape of the lens in terms of actual field of vision where Galen's geometry had stressed the efficiency of Nature. The more practical focus of Ḥunayn encouraged him to recast Galen's arguments wherever it might heighten and clarify practical ramifications. If one chooses to call Galen's two cited works scientific philosophy, then we should call Ḥunayn's *Ten Treatises*—even the first three treatises alone—scientific medicine. Ḥunayn's micro-cosmology, a framework which holds the foundations of visual doctrine together in a consistent visual theory, does not lead to independent theoretical ends. The unity of his visual theory derives not only from cosmological doctrines but also from the crafting of those doctrines into a theory that bespeaks utility and application. The ophthalmologist with complete knowledge of the natures of the parts of the eye and of the instrument of vision will be best informed for any attempt to heal. The later treatises of the *Ten Treatises* depend continuously upon the earlier. Nothing in the earlier, "theoretical" chapters is irrelevant to the later chapters on cures. Ḥunayn's micro-cosmology pertains throughout his *Ten Treatises on the Eye.*

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[219] Ḥunayn, p. 125.

[220] Ibid.

[221] Ibid.

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